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THE BASIS OF SOLUTION BY CHIMPANZEES OF THE INTERMEDIATE SIZE PROBLEM *

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THEORETICAL INTRODUCTION

Almost from the beginning of its discovery in monkeys by Kinnaman (**8**), the phenomenon of transposition has been interpreted as being somehow a relational matter. As the writer pointed out in a previous paper (**15**), however, two somewhat different 'relational' interpretations have been put forward. Köhler (**10**) has distinguished between these two conceptions in the following manner. He speaks of the differential response of the animal to such stimulus situations as two greys as being to their 'togetherness' and he then distinguishes two ways in which this 'togetherness' can occur and be effective: (1) as stimulus wholes or 'Gestalt perceptions' and (2) as perceived stimulus relationships or 'relational-perceptions.' He goes on to state that "it is impossible to explain the former in terms of the latter because the characteristic Gestalt-effect is often at its maximum when nothing whatever of relations is experienced" (**2**, p. 220). According to Köhler, then, the animal is not necessarily responding on the basis of a relational-perception, but only to a structure-function or 'togetherness.' The earlier American investigators, on the other hand, were of the belief that the response was on the basis of a relational-perception (**1**, **7**, **8**), and several recent American psychologists (**11**, **13**) have offered interpretations which more nearly follow the relational interpretation than the Köhler Gestalt theory.

In their recent theoretical article dealing with the problem of discrimination and transposition, Gulliksen and Wolfle (**4**) make a similar distinction between these two theoretical assumptions. They list three hypotheses which have been suggested regarding the aspect

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of the stimulus to which the animal responds in such experiments: (1) that it is the total stimulus configuration, consisting of two stimuli presented simultaneously in a given spatial order (Gestalt theory); (2) that it is the relationship between the stimuli, *i.e.*, brighter, larger, etc. (relational theory); and (3) that the animal responds positively to one of the (absolute) stimuli or negatively to the other. Their own theory is based on the first hypothesis and so is in effect a Gestalt or configuration theory so far as the definition of the stimulus is concerned. However, they depend on the 'law of effect,' which is unacceptable to most Gestalt theorists, in dealing with the problem of learning.

While the majority of experimental findings have shown that the tendency to react to the test situation in a manner which could be interpreted as involving either relational- or Gestalt-perception has been dominant, there has been a considerable number of instances of response contrary to these views. In general, experimental results have shown that transposition tends to fail (1) when the ratio between the original training stimuli is fairly large; (2) when the distance between the training stimuli and test stimuli increases; and (3) in the case of size, when training is to the smaller stimulus and the test is with still smaller stimuli. These inconsistent results have been either entirely ignored by the relational and Gestalt theorists or vaguely accounted for in terms of being beyond the range of equivalence with the training stimuli. To say concerning the failure of transposition at extremes of the size series, as Lashley does, that a pinhead and a cartwheel, unlike a dime and a quarter, just do not belong in the same size series (11), describes the experimental finding in a very picturesque manner. However, it explains nothing. A satisfactory theory must be capable of stating, at least in some degree, the factors which limit the range of transposition of response within a stimulus series. Whether or not the relational theory or the Gestalt theory can or ever will be able to do this, is not our present concern. All that can be stated here is that in their present forms neither has as yet done so. Both find themselves confronted with experimental facts which contradict them.[1]

In the course of attempting to formulate an S-R theory of discrimination learning based on association or conditioning principles, the writer found that the theory, when extended to the problem of discrimination between cue members of a stimulus series such as brightness, size, etc., was able to deduce the phenomenon of transposition. Moreover, the theory led to the further prediction that under

[1] Exception must be made here to the Gestalt theory of these phenomena recently elaborated by Gulliksen and Wolfle (5). Their well-worked-out formulation has shown considerable promise of being able to account for many of the experimental data.

certain conditions transposition should fail to take place. While not completely in agreement with all the available experimental evidence as to the limitations of transposition, the theory was at least a little more capable in this respect than either the Gestalt or relational theories.

The theory of discrimination learning and transposition proposed by the writer has been presented in two previous articles (14, 15). The first dealt primarily with the learning problem, particularly the phenomena of the presolution period, while the second paper elaborated the transposition problem. Briefly, the theory proposes that discrimination learning is a cumulative process of building up the excitatory tendency or association between the positive stimulus cue and the response of approaching it as the result of successive reinforcement, as compared with the excitatory tendency of the negative stimulus to evoke the response of approaching it, which receives only

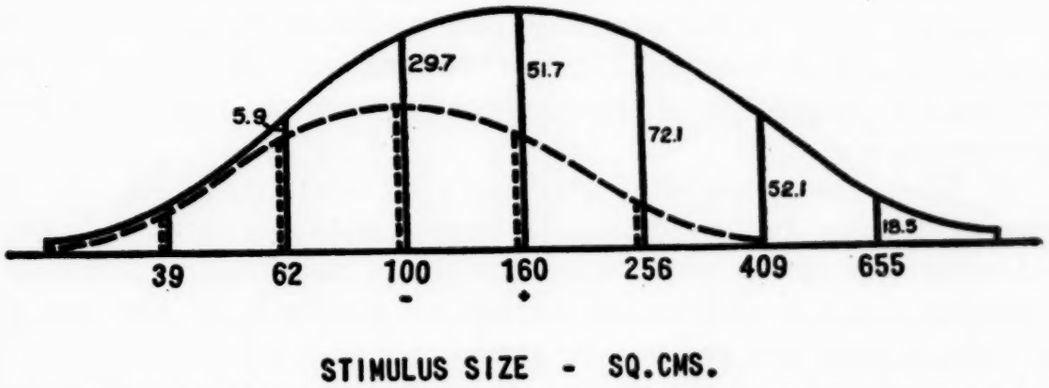

FIG. 1. Diagrammatic representation of the relations between the hypothetical generalization curves, positive and negative, after training on the stimulus combination 160(+) and 100(−).

non-reinforcement. This differential training continues, theoretically, until the difference between the excitatory strengths of the two stimulus cues is sufficiently great to overshadow always any differences in excitatory strength that may exist between other aspects of the stimulus situation which happen to be allied in their response-evoking action with one or the other of the cue stimuli on a particular trial, *e.g.*, the two food boxes or food alleys, which may be allied on one trial with one of the cue aspects and on the next with the other.

In extending the theory to differential response to two members of a stimulus series, certain further assumptions were made. A somewhat modified formulation of the essential characteristics of the hypothesis is presented with the aid of Fig. 1. For purposes of exposition, the experimental situation is assumed to be a size discrimination, the subject being required to learn to go to a stimulus square 160 sq. cms. in area to obtain food, and not to a square of 100 sq. cms. It is postulated:

(1) That, as the result of training or reinforcement, the positive cue aspect (square 160) acquires a super-threshold excitatory tendency (E) to the response of approaching it of the amount represented by the solid line at that point.

(2) That there is a generalization of this excitatory tendency to other members of the size series, and that this generalization follows a gradient such as that represented by the upper curved line.

(3) That with failure of reinforcement of response to the negative cue aspect (stimulus 100), experimental extinction will take place and a negative or inhibitory tendency (I) will be developed to the amount indicated by the broken line at the point on the abscissæ marked 100 sq. cms.

(4) That there is a generalization of this inhibitory tendency to other members of the size series according to the gradient shown by the lower curved line.[2]

(5) That the effective excitatory strength of the size cue at any point in the series is the algebraic summation of these positive (excitatory) and negative (inhibitory) tendencies. This value is indicated by the magnitude of the distance between the upper and lower generalization curves.

(6) That the remaining attributes or dimensions of the two stimulus figures being identical, their excitatory and inhibitory tendencies will cancel each other and hence need not be considered in determining the differential excitatory strengths of the stimulus pair (*e.g.*, square 160 and square 100).

An examination of the hypothetical effective strengths of various stimulus members after learning on the original training pair, which the graph is supposed to represent, reveals that transposition tests with stimulus pairs 256 *vs.* 160 and 100 *vs.* 62 should lead to the predominant choice of the larger stimulus in each case. Thus a deduction of a response which has usually been exclusively interpreted as involving a relational-perception or response to a configuration is shown to be possible on the basis of conditioning or association principles.[3]

As was pointed out in the earlier article (14), we lack sufficient knowledge to make specific postulates as to the nature of the generalization curves, *e.g.*, how they vary with the number of reinforcements,

[2] It will be observed that the stimulus dimension (area) has been plotted on a logarithmic scale, as shown by the fact that the different members (squares) are equidistant from each other. The ratio of the stimulus areas to each other is constant at 1.6 to 1.0. The curves of generalization of the positive excitatory tendency have the equation $E = 100 \times 10^{-cX^d}$, while the equations for the inhibition generalization curves have the form $I = 60 \times 10^{-kX^d}$, where X is the distance in logarithmic units between the test and training stimuli.

[3] The reader is referred to the original article for other details, such as the effect of magnitude of differences between the effective excitatory strengths of the two stimuli, etc.

from individual to individual, etc., and hence it is not possible to make very specific deductions as to exactly what the nature of the results in the transposition tests will be at each point in the stimulus continuum under various conditions of original training and testing. Nevertheless, certain more general implications follow and thus permit an empirical test of the theory. Two such, (1) that the amount of transfer will decrease as stimulus pairs farther removed from the test pair are employed in the transposition test, and (2) that transposition will be less the greater is the difference between the original training pair, have received confirmation in several different experiments involving different conditions and organisms (**3**, **8**, **15**, **20**). More recently, the writer presented the results of experiments involving the effects of special training with isolated stimuli on previously learned responses to stimulus pairs. These data were in striking agreement with the present conditioning theory and not a little embarrassing to the various relational or Gestalt interpretations (**17**).

The Present Problem

The present study reports the results of further experiments concerned with this problem of the basis of differential response by animals to members of a stimulus series. The learning to choose the intermediate of three members of a stimulus series has also been interpreted by some psychologists as involving either response to the relational properties of the positive member or Gestalt-perception. Thus Perkins and Wheeler (**13**), upon finding that goldfish could learn to choose the medium of three different brightnesses, interpreted their behavior as involving perception of the relationship. McCulloch (**12**), employing a somewhat different type of situation in that the animal was required to learn to respond to the intermediate of a series of three weights with only the intermediate and either extreme being presented on any given trial, likewise inferred that his subjects (white rats) reacted, in part at least, on the basis of the membership properties of the positive stimulus, and partly to its absolute properties. Perkins and Wheeler have explained this latter type of discrimination not as involving any absolute judgment, but as involving 'two relative judgments forming a complex temporal configuration.'

Warden and his co-workers (**18**, **19**) and Wolfle (**20**), on the other hand, have interpreted their experimental results with this intermediate problem, involving the presentation of the intermediate stimulus with only one of the extremes at a time, as indicating that response was to the absolute properties of the stimulus cue. Wolfle nicely showed Perkins' and Wheeler's 'two relative judgments' inter-

pretation to be incorrect by demonstrating in a special test involving the simultaneous presentation of all three stimuli that response to the absolute (intermediate) stimulus occurred in 142 of 150 choices by five subjects.

The present investigation was carried out in the Yale Laboratories of Primate Biology and employed chimpanzee subjects in an experimental situation which involved learning to choose the intermediate of three different sized squares, *e.g.*, 256, *160*, 100. Tests for transposition to another setting, *e.g.*, 409, 256, 160, were then given at the completion of learning. Our primary interest was to discover whether the chimpanzee would respond to the absolute stimulus of the training combination or to the Gestalt or relational properties of the original stimulus situation.

Experimental Procedure

A. Subjects

Six adult chimpanzees were used in this study. Each had previously been used in multiple-choice experiments and also in various discrimination experiments, including response to size differences. The latter experience consisted, so far as four of the subjects were concerned, in being trained to respond to either the larger or smaller of two stimulus squares differing in area and then, after being tested for transposition, being given reversed training, *i.e.*, to choose the larger if previously trained to the smaller, and vice versa, and a set of further transposition tests.[4] Of the remaining two subjects, Pati learned only a single size discrimination problem and was never given reversal training, while May was never trained differentially to size differences, but was merely run in a situation in which responses to both sized squares were rewarded. During this period, May chose the larger predominantly for a while and then shifted to chance response.

The present experiment was instituted from about five to ten weeks after the completion of the above described work. Just what effect such prior training experiences might have had on the results of the present experiment cannot, of course, be known for sure, as no naïve subjects were available as controls. Presumably, however, the relational or Gestalt interpretation would be that the subjects had first learned to respond in one manner to the Gestalt- or relational-perception and had then learned to make the opposite response to the same stimulus configuration. Training to the new combination of three differently sized squares required the learning of a new response. The relation of the earlier training to the results of the present experiment from the point of view of the writer's theory will be discussed in connection with the results.

B. Apparatus and Method

The discrimination apparatus has already been described in some detail (15, 16). Briefly, it consisted of three small food boxes to the front of which were clamped the stimulus forms, white enameled squares cut from No. 28 galvanized iron. The stimulus boxes were presented to the subject by pushing the platform on which they were arranged to a point one inch from the living cage screen, where it was possible for the subject to poke its fingers through the two-inch wire mesh, push open the box, and obtain the food. The incorrect boxes were locked. No corrective response was permitted; instead, the platform was immediately pulled back beyond the reach of the subject and preparations were made behind an opaque screen for the next trial.

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[4] The results of these latter transposition tests were reported at the Dartmouth meeting of the American Psychological Association but have never been published. Briefly, it was found that of twelve transposition tests given six subjects, nine were not in accordance with their most recent (*i.e.*, reversed) training, as the relational theory would presumably expect, while three scores ranged from 60 percent to 90 percent in accord with it. Examination of the data from the point of view of the theory proposed by the writer revealed that eleven of the twelve test results were closely in line with it.

Fifteen trials were given each day during both the learning and testing series. The different sized squares were shifted about so that each appeared equally often (five times) at the three spatial positions within each daily series. Training continued until the criterion of learning, fifteen correct choices of the intermediate or medium sized square within a daily series of trails, was attained.

Half of the six subjects were trained originally on squares 256, 160, and 100 in area and half on squares 409, 256, and 160. Those trained on the first combination were tested for transposition on the second and vice versa. Transposition tests were given immediately following learning. One was given ten minutes after the completion of the criterion series and a second approximately twenty-four hours later. The subjects were then given further training on the original learning combination until the criterion was again met, whereupon a further transposition test was given twenty-four hours later. All responses were rewarded throughout the transposition trials.

The experiment was further continued by having the subjects learn to respond to the medium sized square of the combination previously used in the transposition tests and then testing for transposition with the original learning combination. Thus a subject which originally learned with the 256, 160, 100 square combination and was tested with the 409, 256, 160 setting, was now trained to choose square 256 of the latter and was tested for transposition on the former, etc. Two transposition tests, a ten-minute and a twenty-four-hour one, were given subsequent to this latter reversed learning. The experimental work was carried out daily, usually in the forenoon.

Experimental Results

The experimental data for the individual subjects pertaining to the original learning and the transposition tests following it, are contained in Table I. The first column gives the name of the subject and the second the total number of trials, including the criterion series, required to learn. The next column shows the distribution of

TABLE I

Showing the number of trials to learn original problem of choosing medium square, the distribution of responses on the first day of learning series to the three stimulus squares employed in original learning, and the number of choises in subsequent transposition tests involving a different setting of the largest (L), medium (M), and smallest (S) square. The first three subjects learned on setting: L—256, M—160, S—100, and were tested on setting: L—409, M—256, S—160. For the remaining three subjects the settings were the reverse.

Subject	Learning				Transposition Tests								
					First 10-Minute			First 24-Hour			Second 24-Hour		
	No. Trials	L	M	S	L	M	S	L	M	S	L	M	S
		256	*160*	*100*	*409*	*256*	*160*	*409*	*256*	*160*	*409*	*256*	*160*
May	225	4	6	5	0	1	14	0	5	10	0	1	14
Bokar	75	9	4	2	0	5	10	3	9	3	5	8	2
Pati	135	9	4	2	0	1	14	0	6	9	0	6	9
		409	*256*	*160*	*256*	*160*	*100*	*256*	*160*	*100*	*256*	*160*	*100*
Lia	165	6	5	4	15	0	0	14	1	0	15	0	0
Mimi	135	0	3	12	13	1	1	15	0	0	15	0	0
Cuba	135	4	3	8	12	3	0	15	0	0	13	2	0
	M=145				% Medium—12.2 % Absolute—86.6			% Medium—23.3 % Absolute—73.3			% Medium—18.9 % Absolute—75.5		

Turning to the present 'intermediate' problem, the question for this theory is whether the whole properties which the training and test configurations have in common are discernible by the chimpanzee. Insofar as the new test situation has the same whole properties, the organism will respond in the same manner to it that it did to the original configuration. Unfortunately, Köhler does not provide us with any specific postulates that will permit stating in any precise manner what the limit of equivalence of new test situations is. However, one possible basis for reasoning might be the known results on the two-stimulus-member situation. Employing the same size-difference ratio (1.6 : 1.0) as used in the present experiment, it was found that after training on squares 160(+) *vs.* 100(−) transposition (88.3 percent) took place to the new test combination 256 *vs.* 160 and to the 409 *vs.* 256 combination (78 percent) (**15**). Also, after training on the combination 256(+) *vs.* 160(−), transposition (80 percent) took place in the test combination 160 *vs.* 100. One might be led to hazard the guess, then, that these stimuli were within the range of perceptual equivalence and that after training on the configuration 256, 160, 100 there would be transposition to the test configuration 409, 256, 160; and that after training on the 409, 256, 160 combination transposition would occur to the 256, 160, 100 setting. The experimental results (Table I), however, failed to confirm this expectation for, it will be recalled, the subjects responded predominantly to the absolute stimulus and much less than chance even to the stimulus member that this configuration theory would predict.

The Gestalt or configuration theory of Gulliksen and Wolfle is much more highly developed than the primitive Köhler version. These theorists define the response in spatial terms as response to the left or response to the right. Thus, in the two-stimulus size problem in which response to the larger of the two stimuli is always reinforced and response to the small never reinforced, the subject is assumed to be learning to make a left response on those trials in which the configuration 'large on left and small on right' is presented and a right response when the configuration 'large on right and small on left' is presented. The effective strength of each configuration to elicit its appropriate response is a function of the number of correct and incorrect responses made to it and the number of these same responses made to the other configuration. The effects of training on each configuration are assumed to generalize to other similar configurations according to a gradient very much as postulated by the present writer. By means of certain assumptions as to the learning and generalization parameters, Gulliksen and Wolfle are able to deduce a considerable number of propositions about discrimination learning and transposition phenomena.

Turning to the three-stimulus problem, their theory becomes rather complicated. Such a situation would involve six different configurations. Using S for small, M for medium, and L for large, these six configurations would be as follows: SML, LMS, MLS,MSL, LSM, and SLM. The animal would learn, in the present type of problem, to select or respond to the middle position (door or box) in the case of the first two configurations; to the left for the next two; and to the right for the last pair of configurations. Prediction as to what should occur in a transposition involving a new combination of stimulus numbers, such as in the present experiment, depends upon how far one shifted on the stimulus dimension from the training combination. A slight shift would lead to the expectation that the animal would continue to respond to the medium-sized stimulus. As the test combination shifted farther away from the training one, the transfer would become less. Until specific postulates are made about the degree of generalization, it is not possible to state how far transposition will occur, except to say that it will be less in the three-stimulus than the two-stimulus problem. So far as the present results are concerned, however, they do not offer much encouragement to this theory, for not only was there no transfer to the test situation, but the subjects responded predominantly to the absolute stimulus. Such a result is definitely not in line with expectations based on this theory.

Little or nothing need be said about the relational interpretation. Like the Köhler Gestalt theory, it suffers from the fact that it has no specific postulates from which any deduction can be made.

In applying the conditioning or absolute theory to the present experimental situation, we shall use the same postulates that were involved in the treatment of the two-stimulus problem situation. Moreover, the particular form and empirical constants of generalization curves which predict the transposition that actually occurs on the test situation 409 *vs.* 256 after training on 256(+) *vs.* 160 and on test situation 256 *vs.* 160 after training on 160(+) *vs.* 100 will be used. The question we are primarily interested in is what are the implications of such a theory as to the kind of result to be expected in the transposition test after training to the intermediate-sized of three squares.

Figure 2 represents the intermediate discrimination situation in which the subject's responses to the medium-sized square, 160, are reinforced, whereas responses to squares 100 and 256 are not reinforced. It will be observed that the positive, medium-sized square, 160, receives generalized inhibitory tendencies from both negative stimuli. As two errors are made by chance for each correct response, as compared with one error for each correct response in the two-

stimulus situation, it will be seen that there is as much inhibition developed at each point as at the single point in the two-stimulus situation. The positive stimulus thus receives generalized inhibition from two sources instead of one. On the assumption that there is a

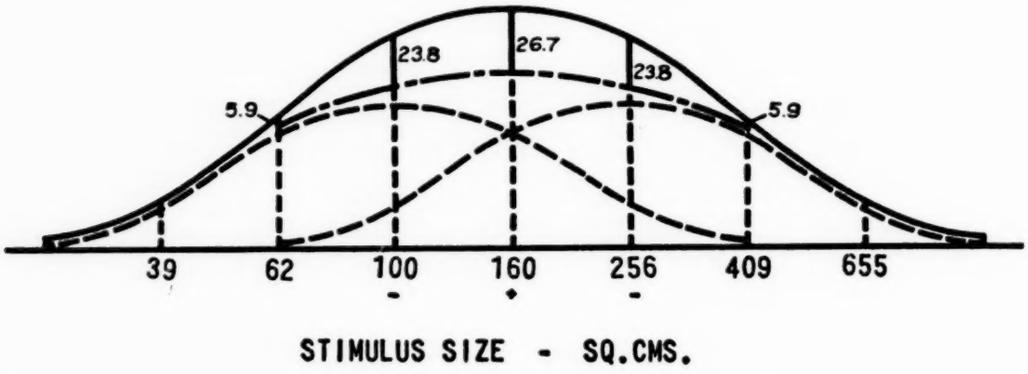

FIG. 2. Diagrammatic representation of the relations between the hypothetical generalization curves, positive and negative, after training on the three-stimulus combination 256(−), 160(+), and 62(−).

summation of these generalized inhibitory tendencies, it will readily be seen that the learning of such an intermediate problem should be much more difficult than learning in the two-stimulus situation.[6]

With regard to the results to be expected on the transposition test, it is necessary to make some postulate as to the summation of the inhibitory tendencies. The assumption made here is essentially patterned after that made by Hull in a similar connection (**6**). The rule implies that the inhibition developing with non-reinforcement approaches a limiting value according to an exponential function instead of increasing infinitely according to a straight-line function. The formula is:

$$I_1 + I_2 = I_1 + I_2 - \frac{I_1 \times I_2}{A},$$

where I_1 = inhibition or generalized inhibition at any stimulus resulting from frustration of response to stimulus 100;

I_2 = inhibition or generalized inhibition at any stimulus resulting from frustration of response to stimulus 256;

[6] In this connection, attention should be called to the claim made by Lashley that an experiment by him in which he showed that white rats learned to choose the largest (or smallest) of three different sized circles much more easily than the intermediate problem (indeed, no progress towards learning was exhibited in the latter) was evidence that the rats responded on a relational basis and not absolute. His argument was based upon an assumption to the effect that "on an absolute basis this (the problem of 'intermediate size') should have been no more difficult than reaction to the largest or smallest" (**11**, p. 165). Whatever 'absolute' theory Lashley may have had in mind, it is obvious that the present formulation does not imply that the 'intermediate' problem would be no more difficult to master than reaction to the largest or to the smallest. His results, far from being contradictory, lend still further support to the present 'absolute' theory.

A = threshold or limit of inhibition at any point on stimulus dimension. It has been assumed that the maximum amount of inhibition cannot exceed the strength of the excitatory tendency at that point.

The dash-dot curve in Fig. 2 represents the theoretical values of inhibition calculated according to the above postulate.

The effective excitatory strength of a stimulus member is taken to be the difference between the excitatory strength and the strength of the inhibition. This value is indicated at the experimental points by the solid vertical lines drawn between the two curves, with the numerical values being given to the right of them. The situation shows that the intermediate stimulus has a strength of 26.7 points and each of the other two stimulus squares strength of 23.8. If this is taken as representative of the state of affairs at the completion of learning, it will readily be seen that the presentation of such a stimulus combination as 409, 256, 160 would lead theoretically to continued choice of the absolute stimulus, 160. Similarly, it may be shown that training to the intermediate square, 256, in the combination 409, 256, 160, would lead to continued response to this same stimulus (256) in the transposition combination 256, 160, 100. This is the type of result, it will be noticed, that was actually obtained in the present experiment.

It is recognized, of course, that the previous experiences of the subjects in the present investigation complicate the theoretical representation of the positive and negative (inhibitory) tendencies they have acquired and that the picture presented in Fig. 2 is not entirely accurate because it omits from consideration the effects of earlier training. Obviously, it is impossible to attempt, in the present state of our knowledge, to represent the effects of such training. It is interesting to note, however, that the single subject, May, that had not received any prior differential training on size discrimination responded very decidedly (38 out of 45 trials) to the absolute square in the transposition tests. Indeed, she responded more definitely to the absolute properties than did either of the other two subjects trained on the same original setting. Also, of no little significance is the fact that Lia, the only other subject that did not exhibit a decided bias for either the largest or smallest member of the original training combination (see Table I), also showed a very clear-cut absolute response in the transposition tests, choosing stimulus 256, to which it was trained originally, in 44 out of the 45 transposition test trials. Both of these cases suggest that the more closely are the theoretical conditions approached, the greater is the agreement between the implications of the theory and the experimental findings.

B. Transposition Tests Following Reversal Training

The second part of the experiment was primarily exploratory in nature. Its object was to ascertain what the effect of the reversal training on the transposition setting of the first part of the experiment would have upon response to the original learning setting. Would the subjects now respond to the intermediate square to which they had originally been trained, *i.e.*, to the configurational properties, or would they continue to choose the absolute stimulus to which they had been last conditioned? Such contrary training in which first one square, *e.g.*, 256, is the positive cue and later it becomes supplanted by a different square, *e.g.*, 160, might lead to a tendency on the part of the organism to adopt a different basis of response than an absolute one.[7]

The results of the transposition tests following this 'reversal' training reveal that there was some tendency to shift from response on an absolute basis, although the results for the group as a whole still favor response to the absolute stimulus. The data of two subjects, Lia and Cuba, suggest that response might have been on the basis of configurational or relational properties of the stimulus complexes. Cuba chose the medium square, 256, on all transposition trials (15) after just learning to choose square 160 in the setting in which it was the medium stimulus. Lia chose the medium stimulus on 12 occasions in each of the two transposition tests.

In order to test further the possibility that these two subjects might be responding on some configurational basis, two further transposition tests were given. The first involved switching back after the two transposition tests to the most recently learned setting, *i.e.*, 256, 160, and 100. In this test Cuba responded eleven times to the intermediate square, 160, three times to square 256, and once to square 100. This result again suggested that this subject was responding to some configurational property. On the other hand, Lia responded in this test predominantly (10 times) to the largest square (256) and only five times to the medium square (160). A still further test was provided by means of an entirely new setting, consisting of squares 160, 100, and 62. The absence of any widely generalized configurational response to the medium-sized of three stimuli was clearly revealed by the choice of the largest square, 160, by both subjects on all fifteen trials.

[7] The factors which make for response on the part of animals to the absolute or configurational properties of stimulus complexes will be discussed in a subsequent paper, reporting further experiments with chimpanzees on the intermediate-sized problem. The present investigation merely attempted to ascertain the effect of a single such 'reversal' of training.

Summary and Conclusions

The basis of differential response by chimpanzees to the intermediate member of three different-sized squares was investigated. After learning to choose the medium-sized of three squares (*e.g.*, 256 sq. cms. in the stimulus combination 409, 256, 160), it was found that the chimpanzees continued to choose the same (absolute) stimulus when it was no longer the intermediate member of a new test combination, *e.g.*, 256, 160, 100. Reversal training to the intermediate member of the test combination led to some evidence on the part of two of the six subjects of limited response on a configurational basis. The remaining four subjects continued to respond definitely on an absolute basis. The results are shown to support the writer's 'absolute' type of theory of transposition and to contradict, insofar as it is possible to do so, the Gestalt and relational interpretations.

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FACTORS DETERMINING CONFLICT REACTIONS IN DIFFICULT DISCRIMINATIONS [1]

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Pavlov's (**13**) studies of experimental neurosis in animals have clearly shown that after animals have been trained to make a discrimination between two stimuli, a reduction in the difference between the magnitudes of the two stimuli will produce disruptions of the well-established discriminatory response. The results of those studies have been amply corroborated by Liddell, *et al.* (**10**), Gantt (**3**), and Cook (**2**). These investigators have been chiefly interested in the specific characteristics of the neurosis, its duration, methods for its production, and in its resemblance to clinical phenomena. They have not, however, made extensive attempts to understand how the disruption of normal discrimination habits is affected by strength of motivation, strength of punishment, difficulty of discrimination, and the like. It is with these problems that the present paper is concerned.

In previous papers by N. E. Miller and the writer (**12**) an attempt has been made to apply the principle of conditioned-response generalization to the interpretation of the conflict behavior which rats exhibit in a short straight alley when two oppositely directed response tendencies (*i.e.*, approach and avoidance) are simultaneously incited. The results achieved there encouraged the belief that perhaps similar concepts might be used in analyzing the conflict behavior which frequently appears in situations demanding the solution of difficult discrimination problems.[2]

As a preliminary step in that direction, the writer has made a study (**1**) of the generalization of approach responses in a non-discrimination situation. The results of that study indicate that when a rat's responses of approaching a stimulus patch of a given brightness have been reinforced by food reward, similar responses will be evoked when the brightness of the stimulus patch is changed.

[1] This study formed a portion of a dissertation submitted to the faculty of Yale University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Psychology. It was financed in part by the Institute of Human Relations, and was conducted under the direction of Dr. Neal E. Miller, to whom the author is indebted for suggestions and criticisms.

[2] Although the concept of generalization has been applied to the interpretation of discrimination learning and transposition by Spence (**15**) and by Jackson *et al.* (**6**), it has not previously been applied to conflict behavior.

Furthermore, the vigor of the approach responses decreases and their latency increases as the test stimuli are shifted along the brightness continuum from the originally reinforced stimulus. When the strength of the approach motivation is decreased, the gradient of generalized responses shows an over-all decrease in height.

Since these results indicate that instrumental acts (such as approaching a brightly lighted region for food) appear to generalize in much the same way as do responses conditioned in the classical Pavlovian manner, we are perhaps justified in extending the concept of generalization to discrimination situations in which both approach and avoidance tendencies are operating.

Theoretical Analysis [3]

Let us first assume that after a certain amount of training in a discrimination problem, an animal possesses tendencies to approach the positive stimulus and tendencies to avoid the negative stimulus.[4] Let it be assumed further that the positive and negative stimuli lie at different points on the same stimulus continuum. Now, on the basis

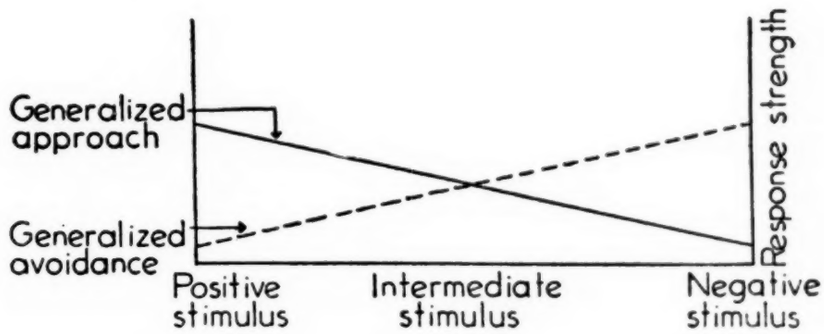

Fig. 1

of the principle of generalization, it follows that the tendencies to approach will generalize from the positive stimulus toward the negative, the strength of the tendency decreasing with distance along the continuum. Similarly, the avoidance tendencies will generalize from the negative toward the positive.[5] This situation is represented schematically in Fig. 1. There the strength of the generalized tendency to approach is shown as a solid line, and the strength of the

[3] The theoretical analysis presented in this section was developed in collaboration with Dr. Neal E. Miller, who has presented a less detailed report elsewhere (11).

[4] In the present study no specific assumptions are made about the mechanisms operating during the acquisition of a discrimination habit. The problem of whether animals learn because successive increments are added to the approach and avoidance tendencies, as Spence (14) has suggested, or whether they learn by the adoption of 'hypotheses' as Krechevsky (8) has maintained, is beyond the scope of this paper.

[5] The approach and avoidance tendencies will, of course, also generalize away from each other along the stimulus continuum. For the present theory, however, this is of no concern.

generalized tendency to avoid is shown as a dashed line. For convenience in presentation, the gradients have been represented as linear and with approximately equal slopes. However, neither of these assumptions about the shape of the gradients is essential for the argument to be presented.

An examination of Fig. 1 indicates clearly that on the basis of the above assumptions, the approach and avoidance gradients must intersect at some stimulus value intermediate between the positive and negative stimuli. This means that the tendencies to approach and avoid that intermediate stimulus will be equal in strength.

Now, from these assumptions it is possible to deduce the well-known fact that a reduction in the absolute difference between the positive and negative stimuli will make the discrimination more difficult. If we assume that the difference between the two stimuli is reduced by making the positive stimulus more like the negative, and the negative more like the positive, it follows that the difference in the relative strengths of the approach and avoidance tendencies will also be reduced. Such a decrease in the relative strengths of the two tendencies should lead to less rapid and accurate responses on the part of the animal. Presumably, if the change in stimulus values is such as to produce a symmetrical change in the strengths of the two tendencies, a point will eventually be reached where the stimuli arouse antagonistic tendencies so nearly equal in strength that the animal will refuse to choose either stimulus. This type of disruption of a discrimination habit will be referred to hereafter as *blocking*.[6]

The limiting case of the increasingly difficult discrimination is that in which the difference between the two stimuli is reduced to zero. Let us now consider what differential effects might result from the presentation of several such pairs of identical stimuli at different points along the stimulus continuum.

The simultaneous presentation of two positive stimuli constitutes what is essentially an approach-approach conflict situation.[7] Now from previous experimental work on conflict, and from theoretical considerations given elsewhere (12), it can be predicted that in such a situation an animal will approach one of the stimuli with scarcely any hesitation. Repeated presentations of two positive stimuli, with approach to either one rewarded, should result in a disruption of the normal discrimination habit which would take the form of persistent random choices or the adoption of a position habit. This type of

[6] A more picturesque term, *encysting behavior*, has been proposed by Lewin (9) to describe similar non-choosing behavior in children.

[7] The approach-approach conflict situation is equivalent to Lewin's (9) Type I conflict. Experiments by Hovland and Sears (5), Klebanoff (7), and Godbeer (4), have all shown that in such a situation almost no conflict occurs.

disruption may be called *indiscriminate approach*, and will be referred to hereafter by that term.

Suppose, however, that two identical stimuli intermediate in value between the positive and negative are presented simultaneously. Since the generalized tendencies both to approach and avoid each stimulus will be approximately equal at that point, a double approach-avoidance conflict situation [8] will be set up and the normal discrimination pattern should break down through the appearance of persistent refusals to choose either stimulus. As in the case of the increasingly difficult discrimination, *blocking* should result.

The simultaneous presentation of two identical or nearly identical negative stimuli constitutes an avoidance-avoidance [9] conflict situation and should result in the elicitation of avoidance responses to both stimuli. If the discrimination set-up permits, the act of avoiding both stimuli at once will result in the animal's withdrawing from the choice point. This third type of disruption of the normal discrimination habit will be referred to as withdrawal, or, following Lewin (**9**), as *going out of the field*.

Although the three types of habit disruption or conflict reactions mentioned above have been treated as if they were distinct, it is evident that there is no sharp dividing line between indiscriminate approach and blocking, or between blocking and withdrawal. Hence it is possible to regard these three types of behavior as members of a behavioral continuum (*i.e.*, a continuum of adjustive responses to a difficult discrimination) ranging from indiscriminate approach at one end, through blocking, to withdrawal at the other end.

What has been said previously with regard to the presentation of pairs of identical stimuli in a discrimination situation, may now be summarized in terms of this behavioral continuum. As the stimuli constituting the pair are shifted along the stimulus dimension toward the positive end, the modal type of adjustive response should shift along the behavioral continuum toward the indiscriminate approach category. Conversely, as the stimuli shift toward the negative end, the modal type of adjustive response should shift toward the blocking and withdrawal categories on the behavioral continuum.

Returning now to the original situation represented by Fig. 1, in which the assumption of simultaneously generalized approach and avoidance responses was made, let us consider what effects changes in strength of drive and strength of punishment should have upon responses to various pairs of identical stimuli. In a previous study (**1**) it has been shown that the over-all height of the gradient of generalized approach responses is increased by heightened hunger motivation.

[8] Hovland and Sears' (**5**) Type IV conflict.
[9] Lewin's (**9**) Type III conflict.

Assuming that the gradient of generalized *avoidance* responses is not affected by an increase in hunger motivation, it follows that an increase in hunger drive will shift the intersection of the two gradients toward the negative stimulus. This situation is presented in Fig. 2.

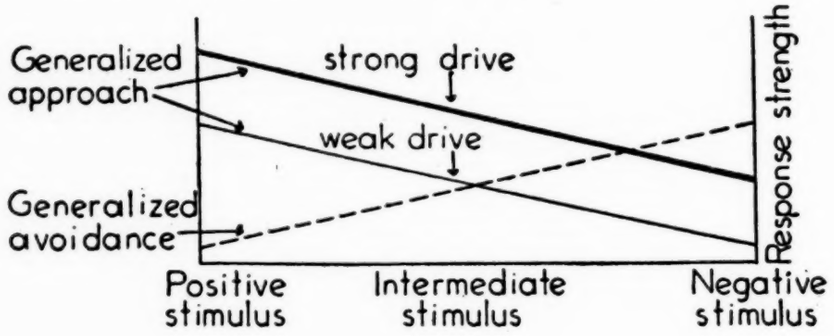

FIG. 2

It follows from this figure that with the increased height of the approach gradient the tendency to evoke indiscriminate approaches will be increased for all of the possible stimulus pairs. For stimulus pairs near the negative end of the continuum this should produce a shift from the withdrawal type of behavior to blocking behavior and for intermediate stimuli it should produce a decrease in blocking behavior and an increase in the frequency of indiscriminate approaches.

It can also be seen from Fig. 2 that a result comparable to that produced by increasing the drive could also be produced by decreasing the strength of shock. This would be followed by an over-all decrease in the height of the avoidance gradient and a corresponding shift of the intersection toward the negative stimulus.

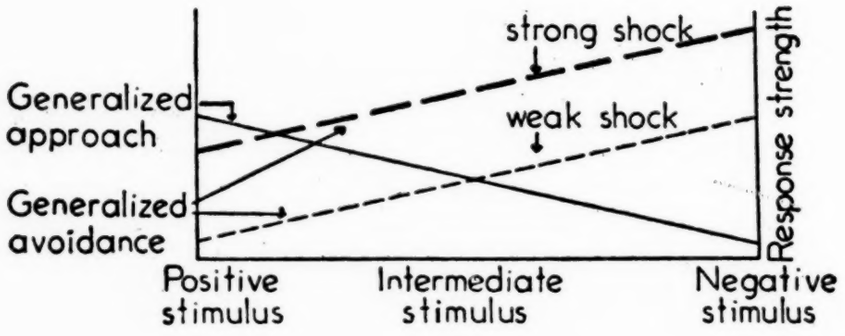

FIG. 3

An increase in strength of shock should produce an effect which is the reverse of that caused by increased hunger drive. This situation is represented in Fig. 3. Here the gradient of approach responses remains constant while the gradient of generalized avoidance increases in height. This causes the intersection of the two gradients to shift toward the positive stimulus, and results in a general increase in the

tendency for all identical stimulus pairs to evoke withdrawal responses. Such an increase would be paralleled by a decrease in indiscriminate approaches and perhaps an increase in the frequency of blockings. Similar effects could be obtained by holding the strength of avoidance constant and decreasing the drive.

Concerning the effects of increased drive or shock upon responses to *difficult but solvable discriminations* we may state that, since the difficult discriminations are usually made up of two stimuli which are similar both to each other and to the intermediate stimulus, responses to the difficult discriminations will closely approximate those given to two identical intermediate stimuli. Thus an increase in drive or a decrease in shock should result in more indiscriminate approaches, whereas an increase in shock or a decrease in drive should produce more withdrawal responses. When the strengths of the generalized tendencies are approximately equal, blocking should be the predominant mode of response.

One point remains to be considered, and that is the effect of *simultaneous* increases in drive and shock. If both gradients are heightened at once, the three types of habit disruption will still be produced by the same sets of stimuli as before. Other more specific effects, such as more head movements at the choice point during blocking, or more frequent and intense withdrawals, although probable, cannot be deduced from the present assumptions.

The general effects of changes in drive, shock, and test stimuli may now be summarized. An increase in drive, a decrease in shock, or a shift of the stimulus pairs toward the positive training stimulus, should produce a shift in the modal disruption pattern toward the indiscriminate approach end of the behavior continuum. Conversely, a decrease in drive, an increase in shock, or a shift of the stimulus pairs toward the negative training stimulus, should cause the modal disruption pattern to shift along the continuum toward withdrawal.

The Experimental Problem

The experiment reported below was designed to test the propositions just considered. A brightness discrimination apparatus was constructed in the form of a Y, with the stimulus patches and food cups at the ends of the branches and a short alley in back of the choice point. This alley provided a region into which the rats could withdraw from the choice point. Provisions were made for recording graphically the exact movements of the animals and for measuring the force exerted by them in their efforts to go out of the field.

Forty-eight rats were trained under a 46 hour hunger drive to make a discrimination between a very dim light and a very bright light. The dim light served as the positive stimulus for half of the animals and the bright light as the positive stimulus for the other half. Half of the members of each of these groups were shocked for approaching the incorrect stimulus, the other half simply received no food. When a learning criterion had been reached, all animals were tested on three impossible discrimination patterns (three pairs of identical stimuli) under two strengths of motivation, a 46 and a 1 hour drive.

The following measures, among others, were made for each animal on each test: (1) time to run to either food cup, (2) number of head movements to right and left, (3) strength of pull in attempting to get out of the field, and (4) distance run backward into alley from the starting point.

After the above tests, the animals were retrained on the original bright-dim discrimination and were then retested on a series of increasingly difficult discriminations. On this 'breakdown' series two strengths of motivation (46 and 1 hour drive) and two strengths of punishment (shock and non-reward) were employed.

The experimental routine for each animal was concluded by administering a series of 6 trials on the original bright-dim discrimination (to test for effects of breakdown upon subsequent easy discriminations) and following this with a final test on a difficult, but not impossible, discrimination.

Apparatus

A schematic diagram of the discrimination apparatus as seen from above, with the out-of-the-field alley and the recording mechanisms, is shown in Fig. 4. The stimulus patches were ground-glass screens (15 × 23 cm.) illuminated from the rear by 500 watt frosted lamps. The brightnesses of these patches could be varied over a wide range by Aubert diaphragms interposed between the lamps and the screens. The screens were mounted in plywood panels which also served to

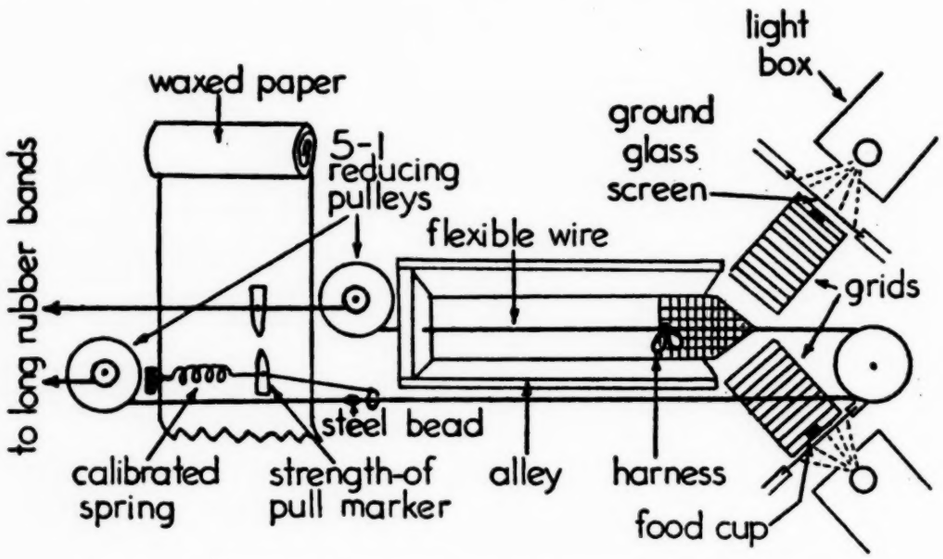

Fig. 4. Diagram of alley recording and strength-of-pull apparatus.

support the two elevated grids leading from the choice point to the two food cups. The grids measured 14 × 23 cm. and were so situated that a gap of 5 cm. was formed between their free ends and the sides of the choice point.

The alley, which extended backward from the choice point a distance of 1 meter, was 12 cm. wide, and 18 cm. deep, with the floor extended 8 cm. beyond the sides to form a right-angle choice point.

The apparatus used to record the position of a rat in the alley and the strength of pull exerted in going out of the field is shown at the left of Fig. 4. During both training and testing, the rats were placed into the harness attached to the flexible wire and were set down at the choice point with their noses approximately even with the end of the alley. On most of the training trials, a single rubber band slipped around the rat's chest served as a harness. On all test trials, however, a dual harness constructed of a rubber band and a coiled spring of stainless steel wire was used. The spring encircled the rat's chest, while the rubber band encircled its neck. This arrangement prevented the animals from slipping out of the harness when pulling against the resistance of the calibrated spring and also, through the steel spring and flexible wire, provided an electrical contact to the rat. This electrical contact was an essential part of the recording mechanism as will be explained below.

The flexible wire to which the harness was attached passed along through the alley near its roof and out through a hole in the end to a compound pulley. From the harness forward, the

wire went between the grids, around a pulley situated in back of the stimulus frames and back again to a second compound pulley near the polygraph, passing along above and slightly to one side of the alley. The natural slack of this system was taken up by two long thin rubber bands.

On all tests, the strength-of-pull marker was connected to the flexible wire by means of a second cord and a snap ring. The snap ring is shown in Fig. 4 at the immediate right of the steel bead. The marker itself was connected to one end of a calibrated spring, which was anchored to the frame of the polygraph. With these connections made, the rat could go forward freely to either stimulus, but if it attempted to back away from the choice point into the alley, the steel bead would engage the snap ring, and the rat would encounter the resistance of the calibrated spring. On all occasions when rats attempted this, they were allowed to pull against the spring for 5 seconds before they were released and allowed to run back into the alley.

The upper one of the two markers shown in Fig. 4 served adequately to record the position of the rats in the alley, but movements to the right or left grids could not be differentiated from its tracings. In order to obtain measures of these right and left movements and accurate time records of approaches to food, a group of four sensitive vacuum-tube-operated relays was employed. These relays were actuated by a subthreshold current flowing from the flexible wire, through the rat's body to the wire mesh at the choice point, or to either grid, or to either food cup. Thus appropriate signal markers would be energized when the rat was sitting at the choice point, when it touched either grid without leaving the choice point, when it made a complete response to either right or left, and when it touched either food cup.

The number of right and left head movements made by a rat at the choice point was recorded manually by the experimenter. Two simple finger-operated levers connected by cords to markers on the polygraph served for this purpose.

The electric shocks used were obtained from a 125,000 ohm potentiometer across the secondary of a 600 volt transformer. A resistance of 2 megohms was placed in series with the rat and the output of the potentiometer for all shocks. The voltages specified as shock values in the description of experimental procedure below were measured across the output of the potentiometer.

Procedure

Training Procedure.—The subjects used were 48 male albino rats between 150 and 200 days of age. During training, the brightnesses of the stimulus patches were set at 0.02 and 5000 apparent foot candles. For half of the animals the dim light served as the positive stimulus, for the other half the bright light was the positive stimulus. These two groups were further divided; half of the members of each group were shocked for making incorrect responses, half simply received no food on the incorrect side.

Before training was begun in the discrimination situation, the animals were given 12 trials in approaching food at the end of a small elevated grid from a short (30 cm.) alley. Each rat received 6 trials per day on the discrimination apparatus until an arbitrary learning criterion of 12 successive correct responses was reached. If an animal reached this criterion before the end of the third day's training its trials were continued through that day in order that all animals might receive a minimum of 18 training trials. All animals were allowed to correct errors by going from the incorrect side to the correct side. The approach training of all animals was conducted on a 46 hour food deprivation schedule.

The position of the positive stimulus, whether bright or dim, was shifted from left to right with successive trials according to the prearranged orders L R R L L R and R L L R R L. The training of half of the animals was started using the first order, and the training of the other half was started using the second order. The orders were alternated on successive days of training. In most cases these presentation orders prevented the development of position habits. In the cases of a few non-shock rats that did develop such habits, several non-correction trials were inserted in order to speed learning. On these trials, the animals were picked up from the incorrect side and replaced at the choice point.

The following voltages were used in shocking animals for errors occurring on each of the first six trials respectively: 0, 100, 200, 300, 400, and 500. On all succeeding days, the shock voltage was held constant at 500 volts except for occasional timid rats, for whom it was reduced to 300 volts.

Testing Procedure.—As each rat successfully reached the learning criterion it was run through a series of three tests. The three tests constitute the main subdivisions of the present experiment.

1. *B-M-D Tests.*—The term B-M-D denotes the fact that bright, medium, and dim stimulus pairs were employed in these tests. Three pairs of *identical stimuli* were used: two brightnesses of 5000, two of 10.8, and two of 0.02 apparent foot candles. For the bright-trained rats, these pairs represented two positive stimuli, two intermediate stimuli and two negative stimuli respectively. For the dark-trained rats they represented two negative, two intermediate, and two positive stimuli.

These three impossible discrimination patterns were presented in completely balanced order. Every rat was tested on each of the stimulus pairs. Twenty minutes elapsed between tests. Food was placed in both food cups and a test was considered terminated when an animal touched either food cup, or if the animal did not reach food, at the end of 2 minutes. No shocks were administered on these tests.

Each animal was tested on the B-M-D series under two strengths of drive, 46 hours and 1 hour. A period of 4 days elapsed between the two tests. All animals were given 6 retraining trials between the first and second tests. Half of the animals were tested in 46–1 order, the other half in the reverse order.

By this procedure, four basic experimental groups were formed:

Group A. 1 hour drive on test. Shocked for errors during training.
Group B. 1 hour drive on test. Not shocked for errors during training.
Group C. 46 hour drive on test. Shocked for errors during training.
Group D. 46 hour drive on test. Not shocked for errors during training.

In subsequent references to these groups they will be designated as: 1 hour drive—shock; 1 hour drive—no shock; 46 hour drive—shock; 46 hour drive—no shock, respectively. In tables, the groups are referred to by letter. Since all animals were tested under both 46 and 1 hour drive, an N of 24 was obtained for each group.

2. *Breakdown Tests.*—Following the last B-M-D test, and an additional day of 6 retraining trials on the original discrimination, all animals were given a series of tests on discrimination patterns of increasing difficulty. On these tests, the bright stimulus was made dimmer and the dim was made brighter. Shocks were given for errors. Since the normal discrimination habit was usually completely disrupted by the end of the sixth test, these tests have been labeled *breakdown tests.* The following brightnesses in apparent foot candles were used as stimulus pairs on successive trials: (1) 0.02 and 5000; (2) 2.32 and 50; (3) 3.87 and 29.9; (4) same as No. 3; (5) 6.47 and 17.9; (6) same as No. 5. These stimulus pairs will be referred to hereafter by the following numbers: 1, 2, 3, 3′, 4, and 4′. The positive stimulus in each of these 6 tests was presented in R L R L R L order for half of the animals and in L R L R L R order for the other half. The order used for a particular animal was determined by randomization. Half of the 48 animals were broken down under 46 hour drive, the other half under 1 hour drive. Here again, four experimental groups result from the testing procedure. These are designated as were the groups on the B-M-D tests, but the members of similarly labeled groups are not identical save with respect to the categories of shock and no shock.

3. *Retraining and Easy-Hard Tests.*—In order to determine the effect of the breakdown tests upon performance on a subsequently presented easy discrimination pattern, all animals were given a series of 6 recorded retraining trials on the original discrimination. These trials followed the breakdown tests by 48 hours. After these retraining trials, the animals were each given two final trials in counterbalanced order, one on the original easy discrimination, the other on a relatively hard discrimination between brightness values of 3.86 and 29.9 apparent foot candles. This hard discrimination was the same as discrimination No. 3 in the breakdown series.

Results and Discussion

Results of the B-M-D Tests.—The results of the B-M-D tests as revealed by four measures, time to run to the food cup, total number of right and left head moves made at the choice point, maximum pull exerted in attempts to go out of the field, and distance moved backward from the starting point, are summarized in Table I. The data

TABLE I

Results of four measurements made on the B-M-D tests. The mean scores for each experimental group on each of the three stimulus pairs are presented. The critical ratios in the second column from the right indicate the reliabilities of the differences between responses to stimulus pairs 00 and 22. The chances in 100 that differences as large, and in the same direction, could have arisen through fluctuations in random sampling are given in the column at the extreme right. In this and in the following tables, the four experimental groups are denoted by letters: A = 1 hour drive—shock, B = 1 hour drive—no shock, C = 46 hour drive—shock, and D = 46 hour drive—no shock.

Measures	Group	Stimuli			Diff. / σ Diff.	Chances in 100
		0 0	1 1	2 2		
Mean time to cup in seconds	A	32.1	35.8	58.7	2.7	<1
	B	15.3	29.4	33.2	2.1	2
	C	4.2	7.4	19.3	2.2	2
	D	1.9	3.4	6.4	2.1	2
Mean number of head moves	A	3.1	3.7	4.2	1.0	17
	B	2.0	2.3	3.7	2.1	2
	C	1.0	0.9	2.0	1.9	3
	D	0.3	0.7	1.1	1.6	6
Mean maximum pull in grams	A	4.1	16.0	28.3	3.2	<1
	B	4.9	11.5	18.0	2.9	<1
	C	0.7	2.1	8.2	1.5	7
	D	0.0	0.2	1.0	1.0	17
Mean distance back in cm.	A	9.9	11.8	32.6	3.2	<1
	B	8.5	11.5	13.9	1.9	3
	C	0.2	0.3	14.0	2.2	2
	D	0.1	0.6	0.6	0.9	18

on time to reach the food cup, and on strength of pull are portrayed graphically in Figs. 5 and 6.

In Fig. 5, the average times taken by each of the four basic experimental groups to reach either food cup are plotted as functions of the three stimulus pairs. The stimuli labeled 00, 11, and 22, represent pairs of identical bright, medium, and dim stimuli respectively for the bright-trained animals, and pairs of identical dim, medium, and bright stimuli respectively for the dark-trained animals. Hence the stimulus 00 represents the positive stimulus for all animals, 22 the negative stimulus for all animals, and 11 an intermediate stimulus for all animals.

It is evident from Fig. 5 that as the test stimuli shift from positive-positive (00) to negative-negative (22) the mean time taken to run to food increases for all groups. This agrees in general with the findings of Hovland and Sears (**5**), and Klebanoff (**7**) showing that approach-approach situations produce less hesitation and blocking than do avoidance-avoidance situations. It is also clear that with the lower degree of motivation a general increase in time taken to approach food

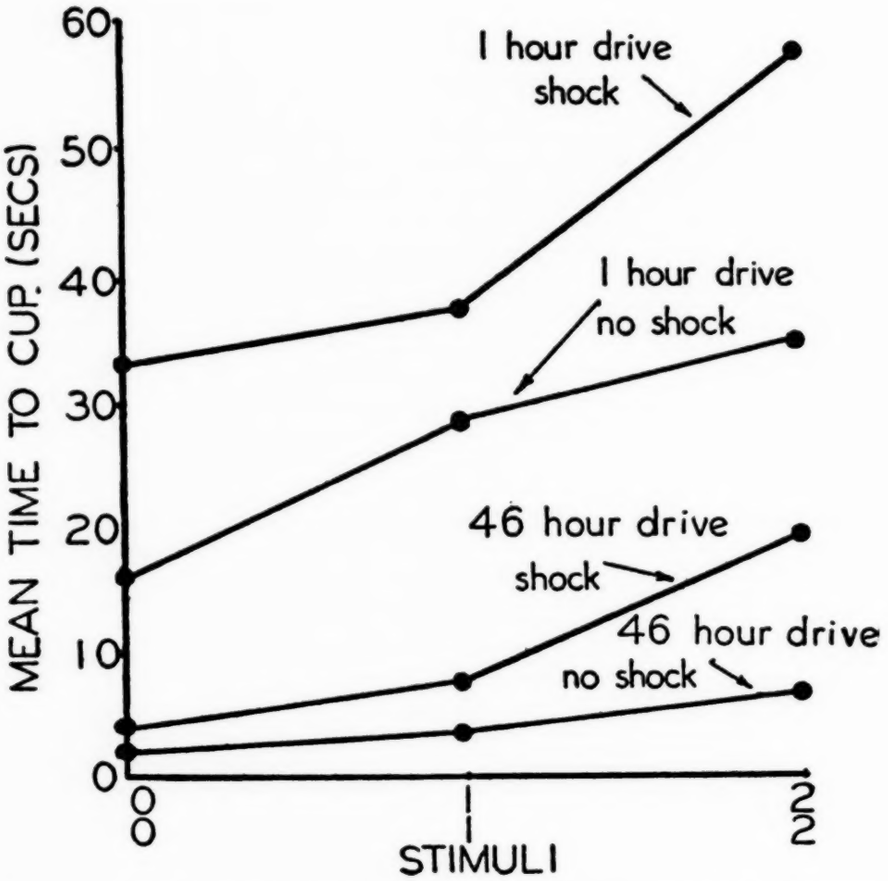

FIG. 5. Results of the tests (B–M–D) in which three insolvable discrimination patterns were presented.

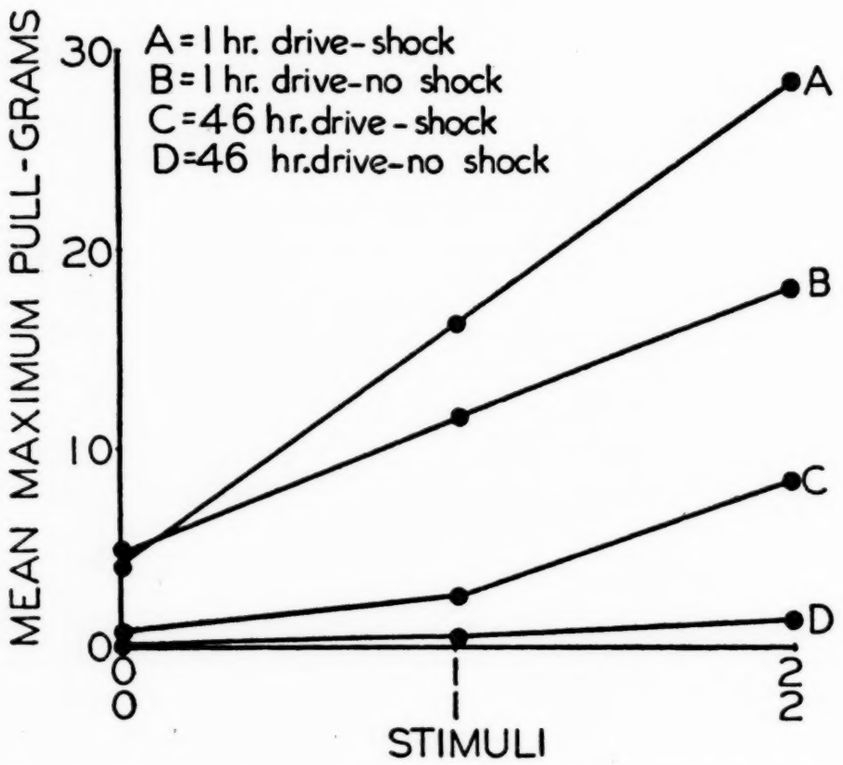

FIG. 6. Mean maximum pull in grams exerted by the members of the four experimental groups in their attempts to go out of the field.

is shown at all stimulus values for both shock and no shock animals, the times for the shock animals being longer than those for the no shock animals. This finding is in accord with one of the deductions made above which stated that with decreases in approach motivation or with increases in the strength of avoidance tendencies, there should be less tendency for the animals to react to a difficult discrimination by making indiscriminate approaches. A portion of this deduction, that concerning the effects of increased shock, is also supported by the fact that the curve for the group with 46 hour drive and shock is higher than that for the group with 46 hour drive but no shock.

An interesting point concerning the effects of motivation and shock upon simple approach-approach conflict situations also emerges from these data. Previous studies by Hovland and Sears (**5**) and by Klebanoff (**7**) have shown that in the approach-approach situation, little if any hesitation or conflict is produced. Here it is apparent, however, that as the drive is decreased and the shock (though given only when a response is made to the negative stimulus) is increased, progressive increases in hesitancy will be elicited in the approach-approach situation. This result demonstrates the effect of generalization of avoidance responses from the negative stimulus to the positive. Since the tendency to avoid is, through generalization, elicited by the positive stimuli, this apparently pure 'approach-approach' situation becomes a special case of Hovland and Sears' Type IV conflict, *i.e.*, double approach-avoidance.

It can also be seen from Fig. 5 that as a shift is made from strong drive without shock to weak drive with shock (*i.e.*, from the lowest curve to the highest) a proportionally greater increase in response time is elicited by the negative than by the positive stimulus pairs. This also is in accord with previous deductions, following from the fact that the negative stimuli have during training been reinforced directly by shock, whereas the positive stimuli have only been affected indirectly by shock through the mechanism of generalization.

An examination of Fig. 6 indicates that the general results obtained through the use of the time-to-cup measure are paralleled by the strength of pull exerted by the animals in their attempts to go out of the field. Clearly, the greater mean strength of pull exerted by the animals when faced with the negative stimuli is indicative of a disruption of the animals' forward going tendencies and is in accord with theoretical expectation. Also, as in Fig. 5, a shift in the drive-shock relations, from strong drive—no shock to weak drive—shock, produces effects which may be directly interpreted as increased blocking and increased vigor of withdrawals from the choice point. The other measures, mean number of head moves at the choice point, and dis-

tance run backward into the alley, give results which are in substantial agreement with those plotted in Figs. 5 and 6. (See Table I.)

The statistical reliabilities of the differences between responses to stimuli 00 and 22 for the various measures are given in the right hand column of Table I. The figures indicate the chances in 100 that differences as large as those obtained, and in the same direction, might have arisen through fluctuations in random sampling. These values are taken from 'Student's' *t*-table in Yule and Kendall (**16**, p. 536).

The low reliabilities found for the 46 hour—no shock group on the maximum pull and distance back measures are not antithetical to the predictions made in the introduction, since it is to be expected that with a strong drive and no shock, the animals should dash forward immediately to either the 00 or 22 stimulus pairs without pulling out of the field or backing up.

TABLE II

Reliabilities of the differences between responses made by the 1 hour—shock group (Group A), and the 46 hour—no shock group (Group D) when tested in the B-M-D procedure. Comparisons of the responses of the two groups have only been made for the extreme stimulus pairs 00 and 22. Each ratio is based on an N of 24.

Measures	Stimulus Pairs	Group		$\frac{\text{Diff.}}{\sigma \text{ Diff.}}$	Chances in 100
		A	D		
Mean time to cup in seconds	0 0	32.1	1.9	3.2	<1
	2 2	58.7	6.4	4.3	<1
Mean number of head moves	0 0	3.1	0.3	3.9	<1
	2 2	4.2	1.1	2.8	<1
Mean maximum pull in grams	0 0	4.1	0.0	1.9	3
	2 2	28.3	1.0	3.6	<1
Mean distance back in cm.	0 0	9.9	0.1	1.9	3
	2 2	32.6	0.6	4.0	<1

In Table II, the reliabilities of the differences between the 46 hour—no shock group and the 1 hour—shock group have been tabulated. Inspection of this table reveals the fact that in general a decreased drive plus increased shock operates to produce highly

reliable increases in the mean values for all four measures. From the nature of the measures it will be clear that *increases* in time to cup, in head moves, in strength of pull, and distance back are all indicative of a shift in the modal type of disruptive response toward the withdrawal end of the behavior continuum. Since such a shift is apparently produced in all cases by decreased drive and increased shock, the deductions made previously are supported.

2. *Results of the Breakdown Tests.*—It will be remembered that the breakdown tests were conducted on a series of discrimination patterns of increasing difficulty and that the animals in the shock groups were shocked for making errors during these tests.[10] As in the B-M-D tests, two strengths of drive were used, *i.e.*, 46 hours and 1 hour of food deprivation. The same measures were made in both types of tests, but an additional measure, number of errors, was made for the breakdown tests. Since a response to either side was correct in the B-M-D tests, errors could not be recorded there. Graphic and tabular summarizations of the data obtained in the breakdown tests are presented in Figs. 7 and 8, and in Tables III and IV.

In Fig. 7 the mean times taken by the members of the four experimental groups to reach food are plotted against discrimination patterns of increasing difficulty. The values given for points 3 and 4 are averages of two determinations made on each discrimination. The cumulative effect of the shocks received by the animals in the two shock groups is readily apparent. With the increasingly difficult discriminations, the shock groups take longer and longer to run to food, whereas the no-shock groups appear to be but little affected by the increase in difficulty. Although on the first trial of the series, strength of drive is apparently the most important factor producing differences between the groups, on the last trial shock becomes more important. In terms of the deductions previously made it is clear that as the avoidance tendencies are increased by the shocks the modal type of disruption shifts toward blocking and withdrawal.

The fact that the no-shock groups under both conditions of drive show almost no progressive effects from the increasingly difficult discriminations, at least in terms of the time measure, may be accounted for quite well in terms of the assumptions made previously. Since the avoidance tendencies of the no-shock groups were extremely weak, it is evident that the strength of avoidance generalizing to the stimuli composing the difficult discrimination would be negligible.

[10] Shocks were given during these tests in order to increase the strength of the avoidance responses. During the original training, many of the shock animals learned the discrimination without making more than two or three errors, hence their tendencies to avoid the negative stimulus were very weak in comparison to their tendencies to approach the positive stimulus. The average number of shocks received by the animals during training was less than 5, a figure which includes the mild shocks given on the early trials of the first day's training.

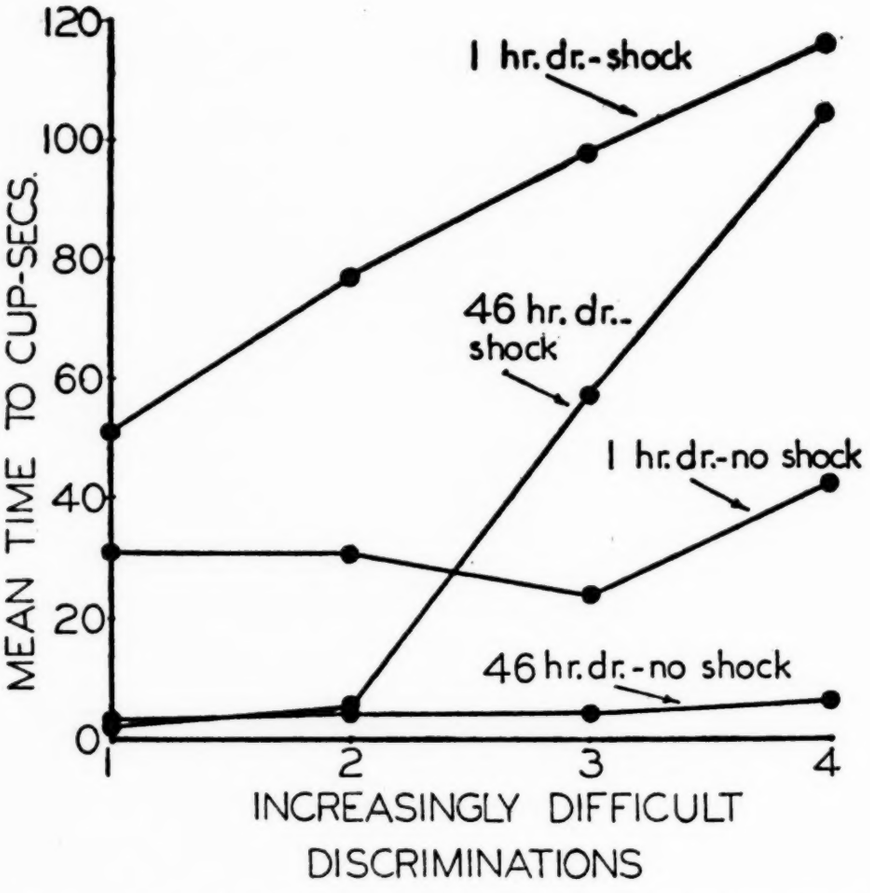

FIG. 7. Average time required to run from choice point to food cup on a series of increasingly difficult discriminations.

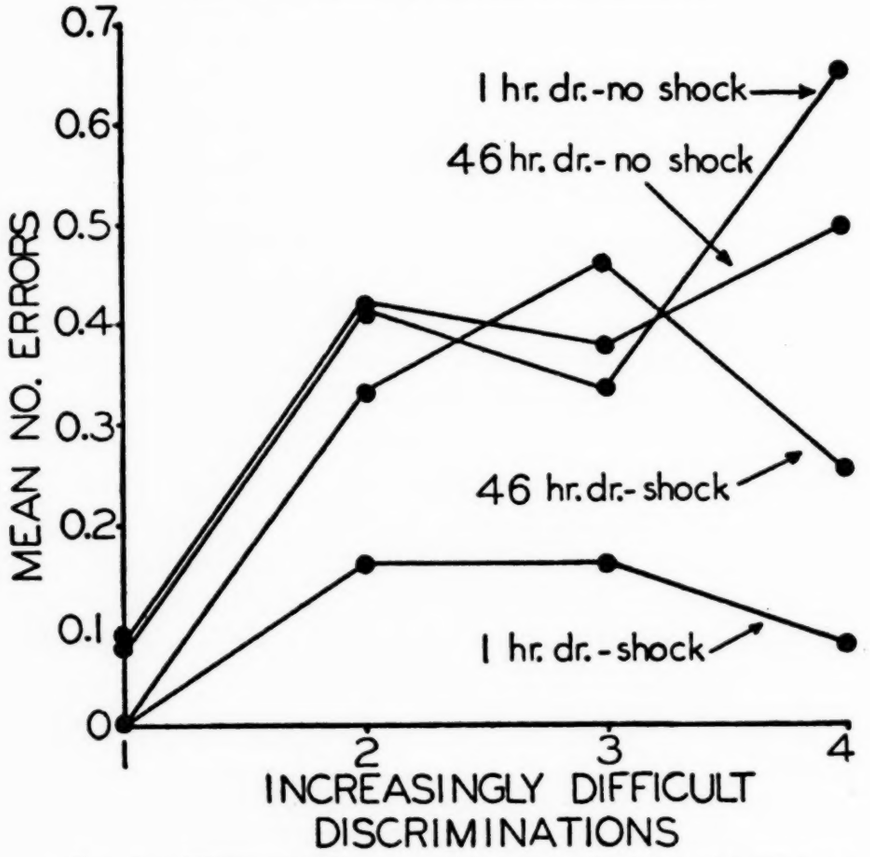

FIG. 8. Effects of different combinations of drive and shock upon the mean number of errors made on a series of four discrimination patterns of increasing difficulty.

TABLE III

Results of the six successive breakdown trials. Figures given in columns headed 3–3′ and 4–4′ are averages of the scores made on discriminations 3 and 3′, and 4 and 4′, respectively. The two columns at the right show the reliabilities of the differences between mean responses made to the easiest (No. 1) and the hardest (No. 4) discriminations in the breakdown series. N = 12 for all of these ratios.

Measures	Group	Discriminations of Increasing Difficulty				Diff. / σ Diff.	Chances in 100
		1	2	3–3′	4–4′		
Mean time to cup in seconds	A	52.5	77.4	97.8	116.0	3.3	<1
	B	31.6	31.2	23.8	42.6	0.6	28
	C	1.4	6.0	57.8	106.0	10.4	<1
	D	1.6	4.9	4.3	5.8	2.1	3
Mean number of head moves	A	1.3	4.3	2.3	1.6	0.9	19
	B	2.2	3.5	2.2	3.1	0.6	28
	C	0.0	0.3	4.0	6.5	3.9	<1
	D	0.0	0.2	0.5	0.2	2.4	2
Mean maximum pull in grams	A	28.1	26.3	49.0	43.1	0.9	19
	B	14.6	12.5	6.7	4.7	−0.8	22
	C	0.0	13.9	37.2	29.8	4.2	<1
	D	0.0	2.5	5.6	4.2	1.2	13
Mean distance back in cm.	A	27.6	36.7	38.9	43.6	1.1	15
	B	21.4	9.3	3.9	10.1	−1.0	17
	C	0.3	7.8	41.0	50.8	5.2	<1
	D	0.0	0.9	3.9	3.4	1.1	15
Mean number of errors	A	0.0	0.2	0.2	0.1	1.5	10
	B	0.1	0.4	0.3	0.6	4.7	<1
	C	0.0	0.3	0.5	0.3	2.6	1
	D	0.1	0.4	0.4	0.5	4.4	<1

TABLE IV

Reliabilities of the differences between mean responses made by the 1 hour—shock group (Group A) and by the 46 hour—no shock group (Group D) on the 1st and 4th discriminations of the breakdown series. These two groups were selected for comparison because they represent the two extremes of drive and shock which were employed. N = 12.

Measures	Discrimination	Group		Diff. / σ Diff.	Chances in 100
		A	D		
Mean time to cup in seconds	No. 1	52.5	1.6	2.9	<1
	No. 4	115.6	5.8	23.4	<1
Mean number of head moves	No. 1	1.3	0.0	1.9	4
	No. 4	1.9	0.2	3.0	<1
Mean maximum pull in grams	No. 1	28.1	0.0	1.9	4
	No. 4	43.2	4.2	2.5	1
Mean distance back in cm.	No. 1	27.6	0.0	2.5	1
	No. 4	43.6	3.4	3.5	<1
Mean number of errors	No. 1	0.0	0.1	0.9	17
	No. 4	0.1	0.5	4.9	<1

In the absence of strong competing avoidance tendencies, the approach tendencies would predominate, and the difficult discrimination would assume the character of an approach-approach situation.

If a graphic plot were made of the values given in Table III for the maximum-pull and distance-back measures, it would be seen that these measures parallel closely those obtained for the time-to-cup measure. The head-move measure is also similar, differing chiefly with respect to the performance of the 1 hour-shock group. When the data for this group are plotted, the resulting curve rises from point 1 to point 2 and then drops progressively to point 4, achieving a final value which is almost as low as the initial one. This effect may be due to the fact that, although these animals spent more time at the choice point than other groups (a statement based upon data not included in this report), they were rarely agitated and frequently 'froze,' making no measureable movement for the full two minute test period. Such states of immobility represent examples of *blocking*, and their manifestation by this group, whose drive was weak and whose avoidance was strong, is in line with theoretical expectation. It should also be noted that any particular value obtained by the head-move measure is meaningless unless it is referred to the specific experimental conditions under which it was obtained. For example, neither the 1 hour-shock group nor the 46 hour-no shock group made many head moves on the fourth discrimination. In the former case this must be interpreted as the result of blocking, whereas in the latter, it must be ascribed to the fact that the animals were running forward indiscriminately.

A count of out-of-the-field responses (irrespective of distance run in the alley) made by the twelve animals of each group during their six breakdown tests yields the following results: 1 hour—shock, 35; 46 hour—shock, 29; 1 hour—no shock, 12; and 46 hour—no shock, 2. These data suggest that as shock is increased and drive decreased, more and more animals go out of the field. A count of the total number of out-of-the-field responses made by animals of all groups on each of the four increasingly difficult stimulus patterns gives values of 7, 10, 14.5, and 16, and indicates, as did the other measures, that with increasingly difficult discriminations, more and more animals respond by going out of the field. The last two of these figures are averages of the two tests made on stimulus patterns three and four respectively.

The measures which have been discussed up to this point have all been of such a nature that as the animals' habits of running forward were disrupted, the values given by the measures increased. In Fig. 8 the results of another measure, the number of errors made on the breakdown series of discriminations, are presented. It is evident

that number of errors, in contrast to the other measures, eventually decreases as the animals' forward-going habits break down, and increase as the animals adopt indiscriminate approach types of response. The curves in Fig. 8 indicate that as the discrimination increases in difficulty the no-shock animals make progressively more errors. The curves for the shocked rats, however, rise for a time and then fall off. Both of these trends are in accord with theoretical expectation. It is of additional interest to note that the 46 hour—shock group made more errors than did the 1 hour—shock group. This too is to be expected, since with a strong drive the modal type of disruption should shift toward the indiscriminate approach end of the behavior continuum, and since number of errors is taken to indicate indiscriminate approaching.

The statistical reliabilities of the differences between mean responses to discriminations 1 and 4 of the breakdown series are summarized in the right hand column of Table III. It is to be remembered that here, as in the case of the reliabilities of the B-M-D tests, a low reliability may be indicative of results which are in agreement with theoretical expectations. In general, it was expected that the no-shock animals would not show highly reliable differences on the two discriminations in terms of the first four measures, but would show such differences in terms of error scores. The reverse was expected for the shock animals. Such expectations are quite in accord with theory since the breakdown of the no-shock animals through indiscriminate approaching should be revealed most clearly by number of errors, whereas the breakdown of the shock animals by blocking and withdrawing should be shown most clearly by increases in response times number of head moves, and the like. The above expectations are not confirmed perfectly by the data given in Table III, but the trend appears to be definitely in that direction.

In order to reduce the labor involved in computing the reliabilities of the differences between responses made under the different drive and shock conditions, only two groups, the 46 hour—no shock and the 1 hour—shock group, have been considered. These two groups represent the extremes of the combinations of drive and shock used in this study. The results of comparisons between these groups on the easiest and the hardest discrimination patterns are presented in Table IV. It will be noted that the reliabilities of the differences between the groups when tested on discrimination No. 1 are not all high. On discrimination No. 4, however, which was presented to the animals after the shock group had received a number of shocks for making errors, all of the differences are reliable. The extremely large ratio of 23.4 is spuriously high because the variability of the distribution of scores made by the 1 hour—shock group on discrimination No.

4 was artificially reduced by terminating all trials at the end of two minutes.

Results of the Retraining and Easy-Hard Tests.—Because of lack of space, the results of these tests will not be treated in detail here. It may be worthwhile to mention, however, certain general results.

The purpose of the retraining tests was to discover what effects the breakdown tests might have upon the rats' responses to a subsequently presented easy discrimination. The purpose of the easy-hard tests following the series of retraining trials was to demonstrate differences between shocked and non-shocked animals on a difficult discrimination in which no shock was given either group for making errors.

When the results are stated in terms of time to cup and other parallel measures, the responses of all groups to the original discrimination pattern were adversely affected by the breakdown series, the shocked rats being more severely affected than the non-shocked rats. In terms of errors, however, the shocked rats were not affected at all, whereas the non-shocked rats were. A differential effect of this sort might certainly be expected since in the breakdown series the non-shocked rats formed habits of running forward indiscriminately which carried over to the retraining situation, while the shocked rats learned either not to chose or to be extremely cautious when making a choice. Although the differences obtained in these tests all maintained a consistent direction, none of them were found to be highly reliable statistically.

The results of the final easy-hard tests indicate that in terms of most of the measures the rats did more poorly on the difficult than on the easy discrimination, in spite of the fact that no shock was administered at the time of the test. Increases in running time, maximum pull, number of head moves, and distance run backward into the alley were noted. These increases were highly significant for the first two of these measures, and only moderately so for the last two.

A final point emerges from these tests, which, though without good experimental support, might be of interest for further experimentation. When the data are analyzed with respect to the differential effect of breakdown under different conditions of drive upon subsequently presented easy discriminations, it appears probable that if an animal's habits are disrupted under a weak drive, the effects will be more severe than if a similar disruption takes place under strong motivation. Since in the present experiment, the two groups could not be equated for amount of disruption, this suggestion must remain at the speculative level.

The extent to which the results of the present study are applicable to human conflict cannot, of course, be determined without direct

experimental test. It may be pointed out, however, that the theoretical principles advanced here seem immediately relevant to certain kinds of conflict reactions. Thus, for example, individual A may react in a strongly ambivalent manner toward individual B *even upon first meeting him.* Such a reaction might be due to the fact that individual B resembles two persons, one of whom A hates, and one of whom he loves. By the principle of generalization, both approach and avoidance reactions are immediately incited in A by B, and conflict results.

Summary and Conclusions

1. A study was made of the behavior of rats in a brightness discrimination situation in which easy, difficult, and impossible problems were presented. From assumptions concerning the generalization of approach and avoidance tendencies in such a situation, simple deductions about the expected behavior were made.

2. The discrimination apparatus was constructed in the form of a 'Y' with the stimulus patches located at the ends of the branches. A short alley placed in back of the choice point constituted an out-of-the-field region into which the rats could withdraw.

3. A group of 48 rats was thoroughly trained under strong drive to make a discrimination between a bright light and a dim light. Half of the animals were shocked for approaching the negative stimulus, whether bright or dim, the other half simply received no food. All animals were given three types of tests: (1) tests under strong and weak drive on three impossible discrimination patterns, the components of which were (*a*) the same as the positive stimulus, (*b*) the same as the negative stimulus, and (*c*) the same as a stimulus intermediate between negative and positive; (2) tests under strong and weak hunger drive on a series of discriminations of increasing difficulty; and (3) retraining tests, under strong drive only, on the original easy discrimination, with a final test on a difficult discrimination. On these tests, measures were made of time taken to approach food, number of right and left head moves made at the choice point, maximum pull in grams exerted in attempts to go out of the field, distance run out of the field, and number of errors.

4. The kinds of behavior which are obtained when a difficult or impossible discrimination is presented may be arranged along a continuum varying from indiscriminate approaches at one end, through blocking (refusal to choose), to going out of the field or withdrawing, at the other end. In terms of the above measures, these types of behavior are best reflected by number of errors, head moves, and strength of pull, respectively.

5. The results of the first tests indicate that when two identical positive stimuli are presented, indiscriminate approaches predominate. As the stimuli are shifted toward the negative stimulus, the

modal type of resolution shifts toward the blocking and withdrawal end of the behavior continuum. Increases in strength of drive or decreases in strength of shock produce a shift in the modal type of resolution toward indiscriminate approaching, whereas decreases in drive or increases in shock produce a shift in the opposite direction.

6. On the series of increasingly difficult discriminations, the rats' normal behavior showed progressive disruption. Animals operating under strong drive with no shock, showed a preponderance of indiscriminate approaches as revealed by number of errors. Animals with weak drive plus shock showed a preponderance of blocking and withdrawal responses.

7. The final retraining tests showed that the disruption of the discrimination habits during the preceding tests had a detrimental effect upon the animals' responses to the original easy discrimination.

8. The results of the tests were in substantial agreement with deductions derived from assumptions concerning the generalization of approach and avoidance responses to stimuli differing in brightness.

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AN ANGLE BOARD AND HAND USAGE STUDY OF STUTTERERS AND NON-STUTTERERS

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I. Introduction

This study represents primarily an attempt to compare an essentially unselected group of young adult stutterers with an essentially unselected group of young adult non-stutterers in terms of scores on the Iowa simultaneous writing angle board test for handedness, and in terms of hand usage scores. The point of the study lies in its relevance to the hypothesis that stutterers differ from non-stutterers with regard to the laterality aspects of neuromuscular organization in general, and with regard to handedness in particular, and that stuttering is due, in part at least, to a relative lack of dominance of one cerebral hemisphere in relation to the other, as manifested in a condition of relative ambidexterity (**2**).

The angle board was devised by Van Riper (**4**). He was able to show that groups of strongly left-handed, strongly right-handed, partly right-handed, and ambidextrous normal speakers, so classified by means of a hand usage questionnaire, performed differently on the angle board in terms of mirroring and the hand involved in mirroring patterns drawn by the two hands simultaneously. He also reported that the performance of a group of essentially unselected stutterers was similar to that of the ambidextrous normal group. Further, with the subject drawing at each ten-degree angle from 0 through 90 degrees, he was able to show quantitative laterality differences between these same groups in terms of the average critical angle (the angle at which mirroring first occurred) for each.

II. Problem

It is to be noted particularly that Van Riper's stutterers and non-stutterers were not definitely comparable. He selected his non-stutterers by means of a hand usage questionnaire in order to obtain fairly distinct groups, one highly left-handed, one highly right-handed, one 'partly' right-handed, and the other quite clearly ambidextrous. He did not select his stutterers in this way; he simply used such stutterers as were available. With regard to hand usage, then,

he compared highly selected groups of non-stutterers with an essentially unselected group of stutterers. Insofar as he was able to show differences on the angle board between his groups of non-stutterers, he may be said to have validated the angle board test. But he did not standardize it for a representative population of non-stutterers. His procedure appears to have involved the assumption that non-stutterers generally fall into three categories with regard to handedness, the left- and right-handed and the ambidextrous, and that if stutterers generally tend to resemble the ambidextrous non-stutterers they are essentially different from non-stutterers as a group.

The present study was designed to test the above assumption, and to check the further assumptions implied in the following specific questions:

1. What are the distributions of angle board scores for a group of young adult non-stutterers, and for a group of young adult stutterers, respectively, both groups unselected with regard to hand usage? What differences with regard to angle board performances obtain between these two groups?

2. What is the reliability of the angle board scores in terms of the coefficient of correlation between two sets of scores computed by two independent scorers?

3. What findings are to be obtained by using two different specified methods of scoring the angle board performances?

4. What are the correlations between specified pairs of the different handedness measures used in the present study?

III. Procedure

The procedure is to be described in terms of the tests employed, the method of scoring, and the manner of selecting the subjects.

Three tests were used. The first test given to each subject involved the drawing of a standard pattern (kinæsthetic pattern, as shown in Fig. 1) by both hands simultaneously, while blindfolded.

Numbers represent principal horizontal movements. Circles which sometimes were drawn by the subjects at points *C* and *D* were ignored in scoring the test performances. No horizontal movements were recognized at points *A* and *B*.

The pattern was drawn on a board (angle board) placed perpendicularly to the surface of the table on which it stood. The board, hinged in the middle, was made up of two halves that could be moved from the 'horizontal' or 0 degree position (in which position writing on the board was like writing on an ordinary blackboard), to the 10, 20, and on up to the 90 degree position (in which position writing on the board was like writing on the two outer surfaces of a closed book, or on the two sides of a door standing ajar). The pattern was drawn at each of ten positions or angles, spaced 10 degrees apart, from 0 to 90 degrees. The kinæsthetic pattern is so termed because it is learned by the subject while blindfolded (he never sees the pattern) by moving the end of a stylus, held in both hands, along a groove in a board, the groove being in the form of the pattern. The pattern, the method of learning it, and the administration of the test have been described by Van Riper (4).

The second test was the same as the first, except that it involved a different pattern. This pattern is termed the visual pattern (see Fig. 1) because the subject looks at it—but not at his hands—while he draws it on the angle board. It has also been described by Van Riper (4).

The subject was given a score for the kinæsthetic pattern and one for the visual pattern. He was also given a score for his performance on both patterns considered as one test.[1]

Each subject also answered a hand usage questionnaire after he had been tested on the angle board. This questionnaire, in one form or another, has been used in several previous studies, among them the one by Van Riper mentioned above.

In drawing the patterns on the angle board the possible performances are as follows: (1) Both hands draw the pattern in the correct orientation; (2) both hands draw the pattern in a partially or completely mirrored or reversed orientation; (3) one hand mirrors the pattern com-

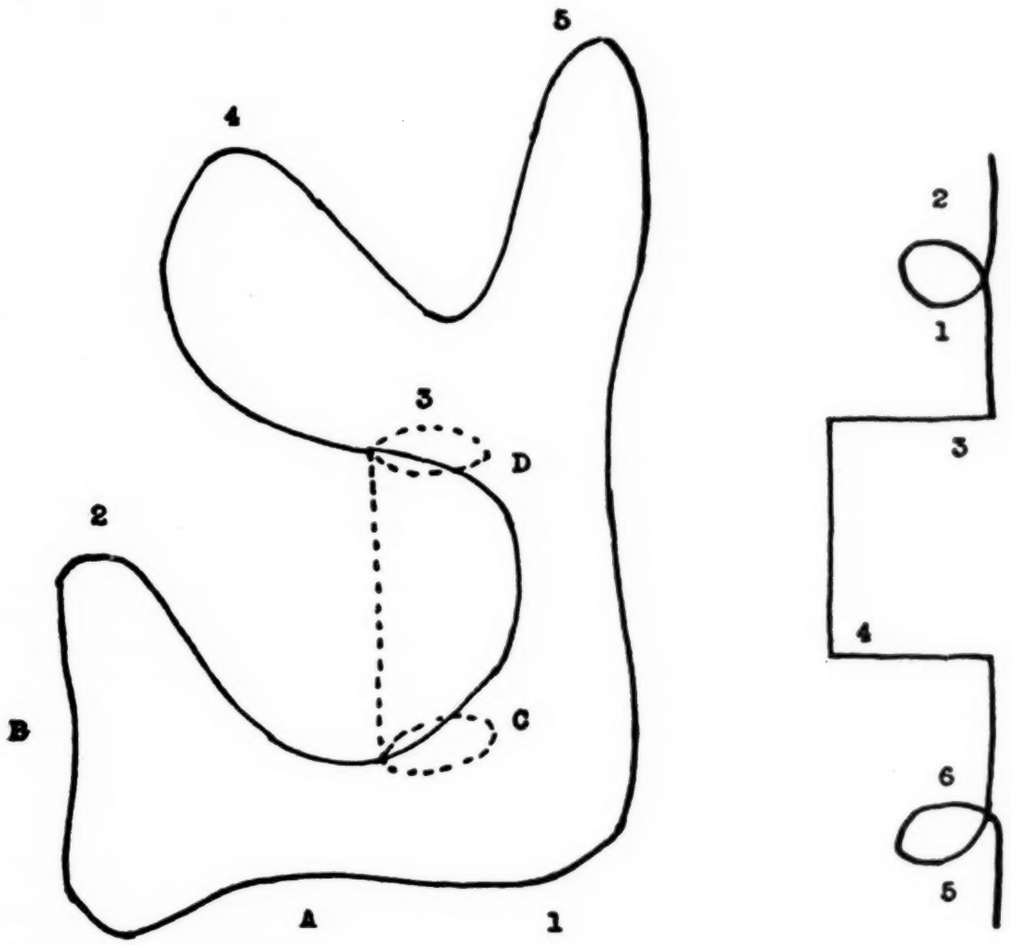

FIG. 1. Patterns drawn on angle board.

Kinæsthetic pattern Visual pattern

pletely or partially. Van Riper scored the test by ascertaining the subject's 'critical angle,' the angle at which he first produced mirroring. It is advantageous to score the test, however, in such a way as to make it more finely differentiating and more readily comparable to other handedness measures. This was done in the present study.

In line with the concept of laterality advanced by Travis (2) and Orton (1), only the horizontal movements involved in the patterns were analyzed, and both patterns were scored in terms of the percentage of principal horizontal movements made normally. The total number of these horizontal movements has been set at five for the kinæsthetic and six for the visual pattern. This is illustrated in Fig. 1. (Points *A*, *B*, *C*, and *D* are explained in the specific scoring rules described below.)

The patterns were scored in terms of the dextrality quotient (DQ) in the following manner: The percentage of horizontal movements made normally was computed for each hand on each

[1] Van Riper also employed a script pattern which was not used in the present study.

pattern at each ten-degree angle from 0 through 90 degrees.[2] The following formula for obtaining the DQ was then applied:

$$\text{Dextrality Quotient} = \frac{R}{R+L}.$$

In this formula R equals the sum of the various ten-degree angle percentage scores for the right hand, L the same for the left hand. This gives, then, two scores for each subject, *i.e.*, one for his productions on each pattern. It is evident that this formula gives the percentage of the total number of normal drawings which are performed by the right hand. A third score for each subject was obtained by again applying the above formula to the kinæsthetic and visual scores together.

The subjects used in this study included 98 adult stutterers, ranging in age from 15 to 37 years, with an average age of 21 years,[3] of whom 81 were male and 17 were female. They were unselected in the sense that they were included in the study only by virtue of the fact that they came voluntarily to the State University of Iowa for speech correction service. There also served as subjects 71 non-stutterers. They ranged in age from 16 to 26 years, the average age being 22 years; 55 were male and 16 were female. They were students in the State University of Iowa, and were otherwise unselected except that they met the following requirements: (1) they had never stuttered at any time in their lives; (2) they had no speech defects at time of test; (3) their arms and hands were in no way deformed or crippled. The non-stutterers were not given the hand usage questionnaire until after they had been tested on the angle board. The questionnaire was used chiefly as a check on the similarity of the two groups of subjects with regard to hand usage.[4]

It remains to be stated that the procedure used in the present study differed from that used by Van Riper in the following additional respects:

1. With the exception of the first 28 non-stutterers tested, all were shown the angle board (but not the kinæsthetic pattern) before being blindfolded and tested, since this facilitated the administration of the test without invalidating the results.

2. The use of a metronome in timing the subject's drawings was omitted. The author simply counted 'One—Two—Three—Ready—Go—Two—Three—Stop' out loud in such a way that the subject, drawing at his maximum speed, could complete the figure in the allotted time.

3. Each subject drew the patterns at all angles from 0 through 90 degrees regardless of the angle at which he began to mirror—if he mirrored at all.

4. Every test was scored by two persons, one of them being the junior author. These two worked independently so that a measure of the reliability of the scoring could be obtained. The scorers were each furnished with a detailed explanation of the scoring system and with the following specific rules:

a. For a given drawing, score each horizontal movement as normal or reversed. The number of such movements will not necessarily be the same for all drawings of a given pattern.

b. Record the score in terms of the percentage of horizontal movements made normally. If a given movement appropriate to the pattern is neither reversed nor made normally (omitted as a horizontal movement) it is not to be scored.

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[2] In a few cases the subject either did not draw the figure at certain angles, or the scorer was in doubt as to what the score for certain angles should be. In such cases a minimum of seven angles on which the score could be computed was required for a subject's record to be included.

If, at a given angle, the pattern for only one hand could be scored, the pattern for the other hand was automatically omitted also, making it so that the 'R' and 'L' scores (DQ formula) were always based on an equal number of angles.

[3] The normal speakers were tested by the junior author of this study. The stutterers had been tested routinely since 1932 by the senior author and by various other clinicians in the State University of Iowa. Forty-six of them had been tested on the reversed (mirrored) form of the visual pattern, but preliminary work showed that this made no significant difference in their scores on this pattern. Van Riper found this to be true, also. He states (4): "Pattern orientation (involving asymmetry to left or right) was shown to affect the performance of only one subject." The fullest possible information was obtained by the writers concerning the methods used in administering the tests routinely to stutterers, and these methods are not different in any important respects from those used in testing the non-stutterers. All tests, for both stutterers and non-stutterers, were scored by the same methods.

[4] The questionnaire scores for 9 of the stutterers were not available.

c. The movement to be considered as the first movement in a given drawing will always be the first down-stroke.

d. Score a given turn on the basis of the way it is eventually made, ignoring 'false starts.'

e. If, on the visual pattern, there is not a distinguishable loop where there should be one, no part of the given loop is to be scored. This applies even though turns one and five (Fig. 1) have been drawn properly.

f. If a horizontal line drawn vertically at any scoring point in the pattern lies fifteen or more degrees on either side of the true vertical as measured from the nearest horizontal section of line, it is to be scored. Lines lying within fifteen degrees of the true vertical are not scored.

g. Disregard all lines, properly made vertically, which are drawn horizontally. Do not score these as horizontal lines, because they simply constitute errors in the drawing of vertical lines.

h. Do not score more than the numbered turns. If horizontal turns appear at points in the pattern other than those numbered, ignore them. Ignore any horizontal turns that may appear at points *A* and *B*; also ignore circles appearing at points *C* and *D* (see Fig. 1).

In several instances the subject inquired whether he was to give his attention to his 'good' hand (the hand most easily controlled) or to the other hand. In each case he was instructed to draw the figure in whatever way was 'easiest' or 'most natural' for him. One subject [5] interpreted the word 'natural' to mean that he was to forget his 'good' hand and concentrate on the other hand. Evidently still not sure that he was placing the correct interpretation on the word, he again asked, when about half way through the test, just how the figures were to be drawn. Once more he was told to draw them in whatever way was easiest for him. This he interpreted to mean that he was not to concentrate his attention on either hand exclusively. In connection with this he stated that he thought he could induce mirroring at will, and accordingly did so. We may conclude, then, that the use of the word 'natural' should be avoided in describing to the subject how his attention is to be focused, since it may only confuse him, and that it is apparently possible for a subject to control his mirroring.

IV. Results and Discussion

The results of this study may conveniently be divided into the following four parts: (1) correlations between the scores computed by the two persons scoring the data; (2) correlations between the scores made on the kinæsthetic and visual patterns and between these pattern scores and the hand usage questionnaire scores; (3) distribu-

TABLE I

Correlations Representing Scoring Reliability

	Kin.	Vis.	Comb.
Stutterers	.98±.002	.94±.008	.96±.008
Non-stutterers	.98±.003	.99±.002	.99±.003

Legend: Kin. = Kinæsthetic pattern
Vis. = Visual pattern
Comb. = Combined kinæsthetic and visual patterns.

tions of scores and measures of central tendency and variability for the kinæsthetic and visual patterns, these two combined, and the hand usage questionnaire; (4) critical angle scores according to Van Riper's scoring procedure, and group comparisons in terms of the hand by which mirroring was done.

[5] Not included statistically because of obvious changes in the procedure. This subject had a hand usage index score of .03.

Reliability of Scores

Correlations between the dextrality quotient scores on the angle board, computed by two independent scorers, are presented in Table I, for both stutterers and non-stutterers.

It is evident from Table I that the two scorers agreed highly in every instance.[6]

Inter-test Correlations

Table II presents correlations between the kinæsthetic and visual pattern DQ's as well as between these and the hand usage questionnaire DQ's, for both stutterers and normal speakers.

TABLE II

COEFFICIENTS OF CORRELATION BETWEEN THE VARIOUS TESTS

	Stutterers		Non-stutterers	
	Vis.	Quest.	Vis.	Quest.
Kin.	.29±.06	.005±.01	.62±.05	−.15±.08
Vis.		.17 ±.07		.14±.08

Legend: Kin. = Kinæsthetic pattern
Vis. = Visual pattern
Quest. = Hand usage questionnaire.

Analysis of Table II discloses the following principal facts:

1. In the case of the stutterers, the kinæsthetic pattern showed practically zero correlation (.005 ± .01) with the questionnaire. This would tend to indicate that the kinæsthetic pattern test and the hand usage questionnaire are not measures of the same attribute.

2. The correlation of .17 ± .07 between the visual pattern DQ's and the questionnaire DQ's (stutterers' group) shows little direct relationship between the two.

3. For the stutterers the kinæsthetic and visual pattern DQ's showed a correlation of only .29 ± .06.

4. With regard to the non-stutterers, the two angle board pattern scores correlated fairly well (.62 ± .05), though not highly enough for a very definite prediction to be made from one to the other.

5. Little relationship was demonstrated, in the non-stuttering group, between the angle board DQ's and the questionnaire scores. The correlation between the visual DQ's and the questionnaire DQ's was .14 ± .08; the correlation between the kinæsthetic and questionnaire DQ's was − .15 ± .08.

6. The difference between the stutterers and non-stutterers with regard to the correlation between kinæsthetic and visual DQ's, the

[6] In succeeding tables only the junior author's scores have been used.

correlation coefficients being .29 and .62, respectively, is significant at the 1 percent level of confidence, as shown by a C.R. of 2.68. Before attempting any elaborate interpretation of this difference, the present writers would prefer that it be corroberated by other investigators since it does not appear to be particularly consistent with the other findings.

Test Scores

In Figs. 2, 3, 4, and 5 the grouped frequency distributions of the DQ's of both stutterers and normal speakers on the two patterns and the questionnaire are presented graphically, together with the usual measures of central tendency and variability.

The distributions of the kinæsthetic, visual, and combined scores are so strikingly similar that they may well be discussed together. The following principal characteristics are worthy of note:

1. All distributions are unimodal, and tend to be normal.

2. With respect to both the kinæsthetic and visual distributions, the average scores of both groups closely approximate each other, not only on the same pattern, but also as between patterns. The average combined scores of both groups are the same, both being .53.

3. In each set of distributions the range of the stutterers' scores is almost twice that of the non-stutterers'.

4. All S.D.'s, with one or two exceptions, are moderately high, and are somewhat greater for the stutterers than for the normal speakers. This is in line with the greater range of scores shown by the stutterers.

Analysis of the variance of the distributions of the DQ's for the two groups resulted in an *F* value of 1.655 for the kinæsthetic DQ's, 1.961 for the visual DQ's, and 1.55 for the combined DQ's. These *F* values for the kinæsthetic and combined DQ's are significant at the 5 percent point, while the *F* for the visual DQ's is significant at the 1 percent point. Thus, the variability appears reliably greater among the stutterers than among the non-stutterers. This is evidenced particularly, of course, in the greater range of scores for the stutterers, indicating that more of them performed on the tests as extremely right- or left-handed individuals. In light of the tendency of earlier investigators to conclude that stutterers tend to be ambidextrous, and that non-stutterers tend to be definitely unilateral, this finding is especially interesting.

5. Only in the case of the visual pattern does there seem to be even a slight possibility of a significant difference between the stutterers and non-stutterers, as indicated by the critical ratio of the difference between the means, the stutterers having the higher mean DQ (the higher the DQ the greater the degree of right-handedness). In this instance the critical ratio is 1.15.

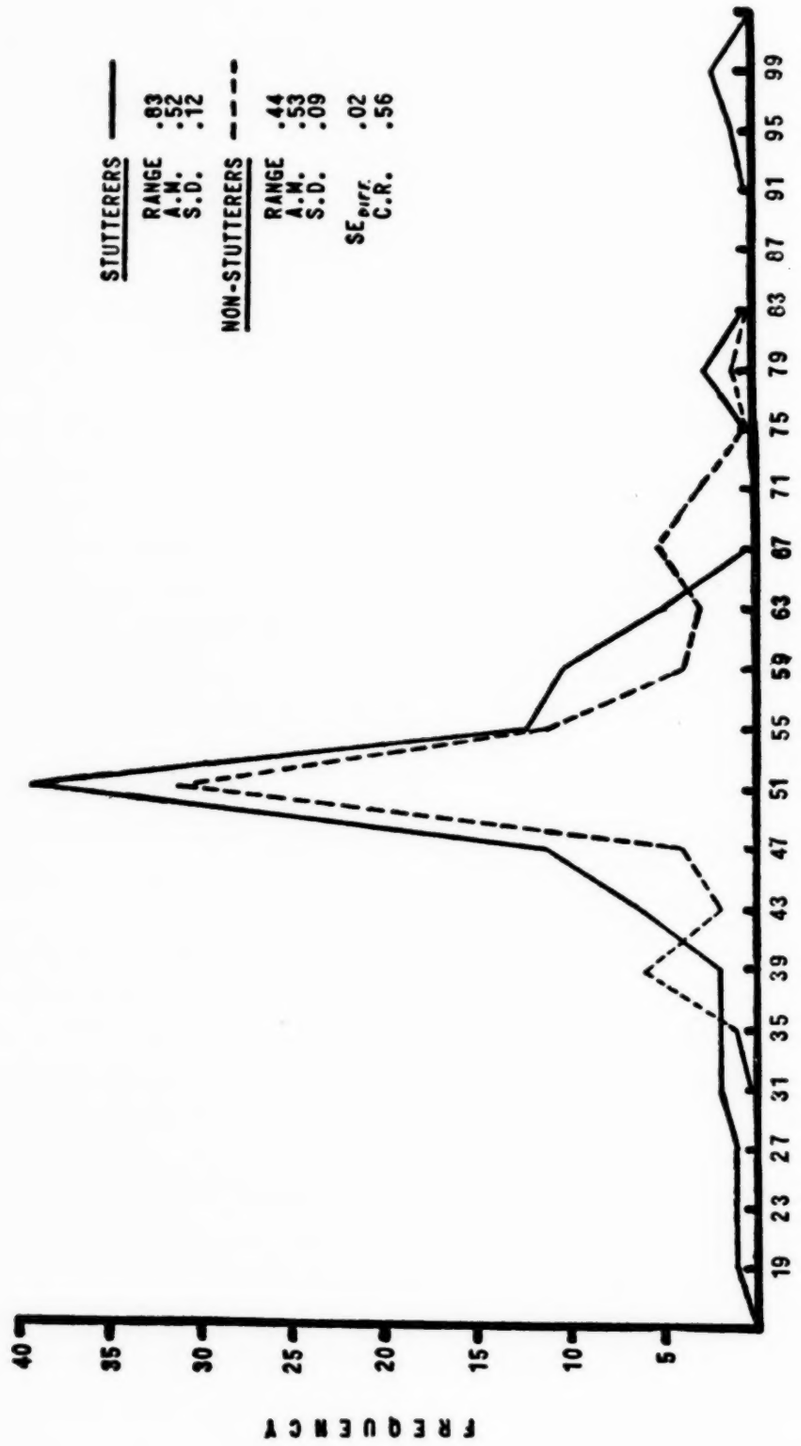

FIG. 2. Stutterers' and non-stutterers' DQ's on kinæsthetic pattern. All measures rounded to two places.

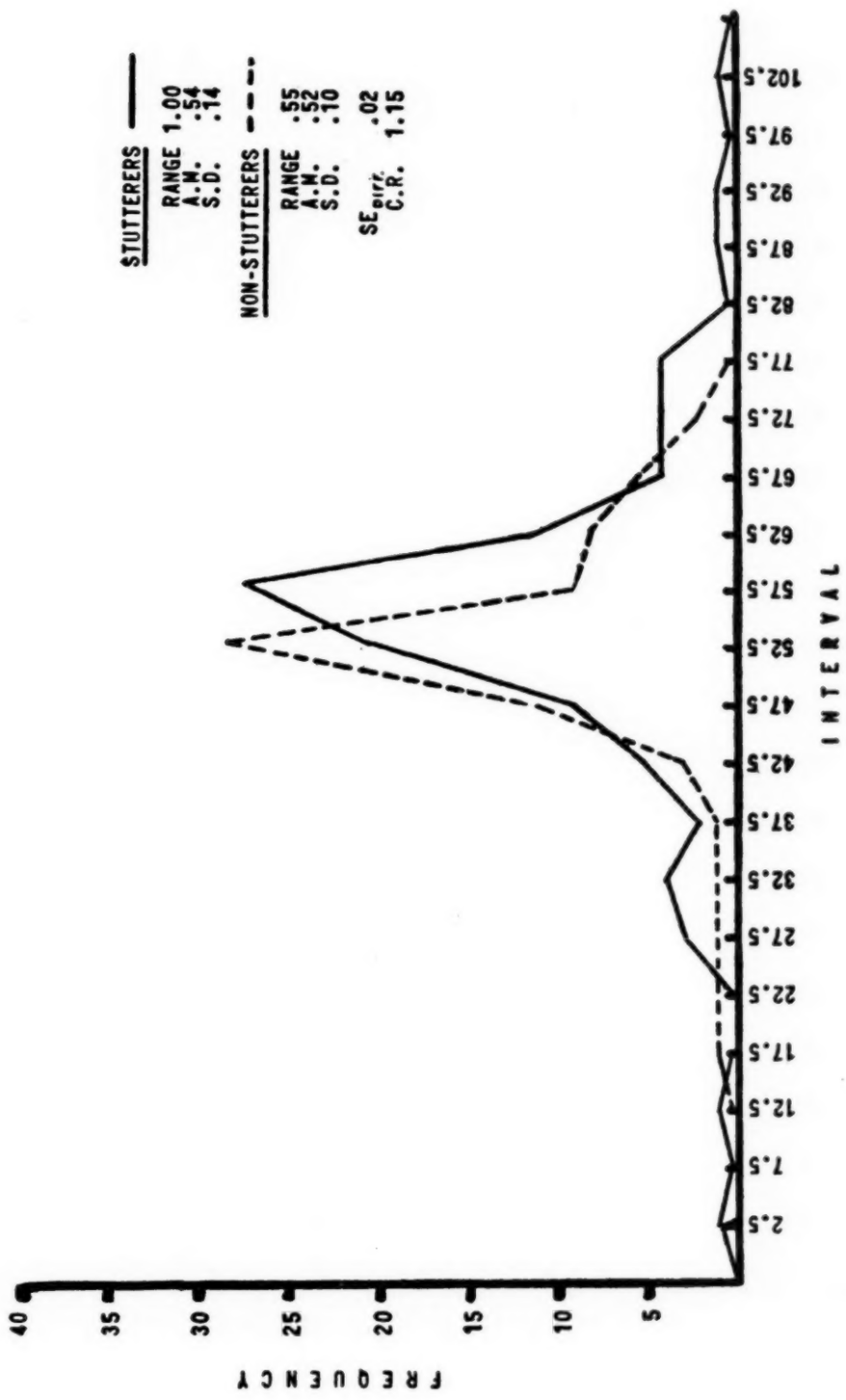

FIG. 3. Stutterers' and non-stutterers' DQ's on visual pattern. All measures rounded to two places.

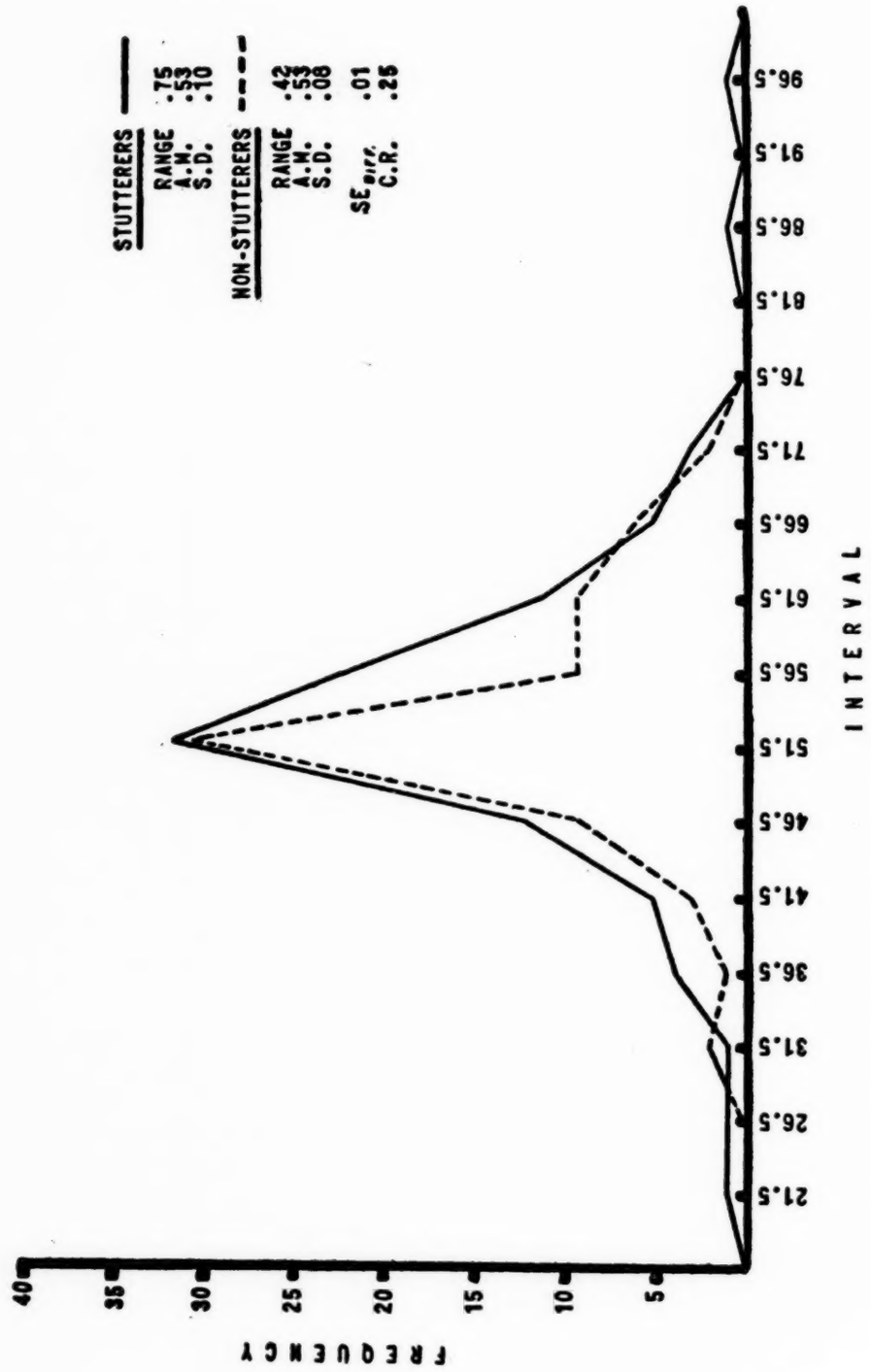

FIG. 4. Stutterers' and non-stutterers' DQ's on kinaesthetic and visual patterns combined. All measures rounded to two places.

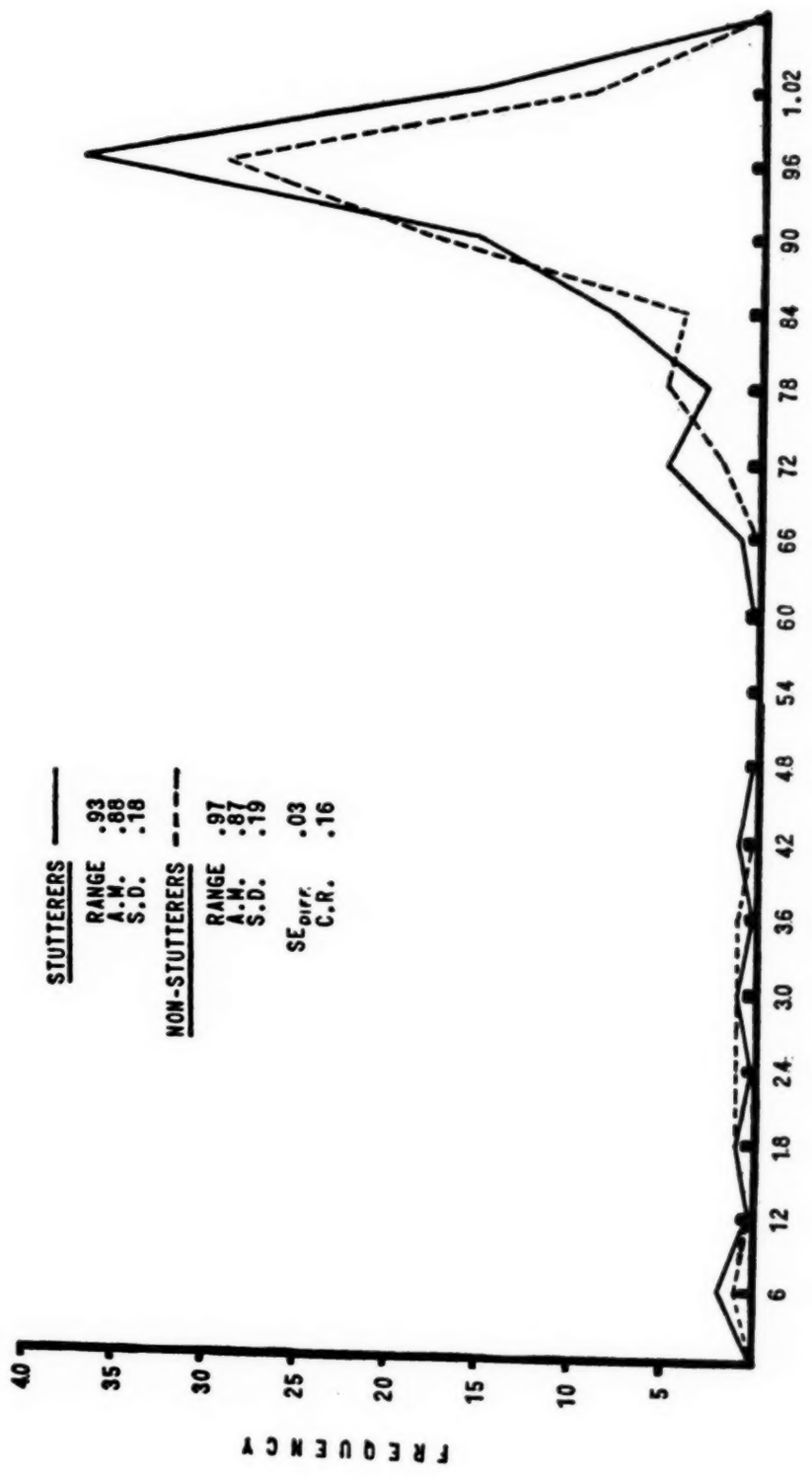

FIG. 5. Stutterers' and non-stutterers' DQ's on the questionnaire. All measures rounded to two places.

The comparative performances of the two groups of subjects on the questionnaire is both similar to and different from their performance on the patterns. The distributions are unimodal but quite negatively skewed. Since there are no important differences between them, it is evident that stutterers and non-stutterers are much alike with regard to hand preference in everyday activities, as expressed on the questionnaire.

TABLE III

DECILE AND QUARTILE DQ SCORES FOR THE VARIOUS TESTS

%ile	Non-stutterers				Stutterers			
	Kin.	Vis.	Comb.	Quest.	Kin.	Vis.	Comb.	Quest.
High	.77	.72	.71	1.00	1.00	1.00	.94	1.00
90	.66	.64	.65	.99	.63	.70	.64	.99
80	.59	.62	.59	.98	.58	.63	.59	.98
75	.56	.58	.58	.97	.56	.61	.58	.97
70	.54	.56	.54	.96	.54	.59	.57	.97
60	.52	.53	.52	.95	.51	.58	.54	.95
50	.51	.51	.51	.93	.50	.55	.53	.93
40	.50	.50	.50	.91	.50	.53	.51	.92
30	.50	.50	.50	.88	.49	.51	.50	.89
25	.50	.49	.50	.86	.48	.49	.49	.86
20	.49	.49	.48	.84	.47	.46	.48	.83
10	.41	.43	.44	.71	.40	.36	.41	.70
Low	.33	.17	.29	.03	.17	0	.19	.07

Legend: Kin. = Kinæsthetic pattern
Vis. = Visual pattern
Comb. = Combined kinæsthetic and visual patterns
Quest. = Hand usage questionnaire.

Table III indicates no marked differences between stutterers and normal speakers in terms of the decile and quartile scores of the two groups. These scores may be considered as tentative norms for both groups.

Critical Angle Scores

As has been indicated, Van Riper (4) scored the angle board test in terms of the 'critical angle.' "The subject then drew the pattern . . . until at some angle a mirrored pattern was drawn. This angle was termed his critical angle. As a check on the accuracy of the performance, a further trial was given at an angle of 10 degrees beyond this" (4, p. 375).

The present writers have assumed that Van Riper meant a *fully* mirrored pattern, and that if on the 'further trial' mirroring did not occur, he continued the test until there were full mirrorings at two successive angles (unless, of course, the first angle at which mirroring occurred was the last or 90-degree angle). The angle board per-

formances in the present study have been scored accordingly with regard to the determination of critical angles. That is, the critical angle has been defined as the first of two successive angles at which full reversals were made by the subject (unless the first full reversal was made at the 90-degree angle, in which case there was no possible 'further trial' and 90 degrees was regarded as the critical angle).

A further word of explanation is necessary. Van Riper (4) does not indicate how he scored a performance in which no full reversals occurred. Several of our subjects gave such a performance. The most practical solution to this problem seemed to lie in scoring all such performances as showing a critical angle of 90 degrees, since 90 degrees is the test limit and, therefore, the nearest possible approximation to the critical angle score of a subject who makes no full reversals. If Van Riper scored such subjects differently—or gave them no score—any differences as to mean critical angles between his and the present study may be accounted for in part on this basis.

It seemed of interest, also, to score the tests still another way, defining the critical angle as that angle at which a partial reversal first occurred. The results of this scoring are presented in Table IV,

TABLE IV

MEAN CRITICAL ANGLES AND S.D.'S FROM VAN RIPER'S STUDY (4) AND PRESENT STUDY

	Visual			Kinæsthetic	
	N.	M.	S.D.	M.	S.D.
Non-stutterers (Van Riper)					
Right-handed	35	27	16	31	15
Left-handed	35	27	16	35	16
Ambidextrous	30	69	18	70	16
Partly R. H.	30	49	25	52	26
Stutterers (Van Riper)	30	67	19	59	15
Present study (full reversal)					
Non-stutterers	71	78	18	74	21
Stutterers	98	68	24	70	24
Present study (partial reversal)					
Non-stutterers	71	66	25	54	32
Stutterers	98	46	26	63	27

along with the results of the critical angle scoring when full reversals were considered. In Table IV Van Riper's findings are given for comparison with present findings. If one may judge from Table IV, Van Riper's ambidextrous non-stutterers were drawn apparently from among individuals fairly representative of the mean of an essentially unselected population, insofar as such a population is represented by the non-stutterers in the present study. It would appear that his right-handed and left-handed non-stutterers were quite extreme groups, and not representative of non-stutterers generally. Van

Riper's conclusion that stutterers resemble ambidextrous non-stutterers on the angle board test would appear to mean only that the average stutterer resembles the average non-stutterer. His implicit assumption that the scores of the ambidextrous subjects were atypical of the scores of non-stutterers generally was hardly warranted; on the contrary, they were apparently the most typical scores of all those presented by his non-stuttering groups.

Partial reversing tends to preceed full reversing by from 10 to 20 degrees, on the average, as shown in Table IV. The generally higher S.D.'s for the partial reversal critical angles suggest that the full reversals are a more stable basis upon which to compute the critical angle. The fact that such a critical angle, however, leaves partial reversing out of account, would seem to indicate that the dextrality quotient score used in the present study constitutes a finer measure than does the critical angle.

The comparative performances of the stutterers and non-stutterers in the present study are presented from another angle in Table V.

TABLE V

PERCENT OF STUTTERERS (N = 91) AND NON-STUTTERERS (N = 71) REVERSING WITH LEFT HAND, RIGHT HAND, BOTH HANDS, AND NEITHER HAND

Kinæsthetic Pattern

	Full Reversal			
	Left	Right	Both	Neither
Stutterers	33.7	28.7	1.0	36.6
Non-stutterers	35.2	19.7	0.0	45.0
	Partial Reversal			
	Left	Right	Both	Neither
Stutterers	49.0	16.4	7.3	27.3
Non-stutterers	45.8	20.8	4.2	29.2

Visual Pattern

	Full Reversal			
	Left	Right	Both	Neither
Stutterers	56.4	19.8	0.0	23.8
Non-stutterers	31.0	21.1	0.0	47.9
	Partial Reversal			
	Left	Right	Both	Neither
Stutterers	56.8	29.7	8.1	5.4
Non-stutterers	52.8	15.2	13.2	18.8

According to Van Riper (4), reversing is done mainly by the non-dominant hand, and he inferred that the angle board performance was indicative, therefore, of the relative dominance of one or the other of the cerebral hemispheres. If the left hand reversed the patterns, it was to be inferred that the left cerebral hemisphere, contralateral to the right hand, was the dominant one, and if the right hand reversed, it was to be inferred that the right cerebral hemisphere, contralateral to the left hand, was dominant. Moreover, the higher the critical angle—the farther the subject progressed with the test before reversing—the smaller the margin of dominance exercised by either hemisphere over the other. Van Riper's right-handed subjects practically all reversed with the left hand, his left-handed subjects reversed with the right, and his ambidextrous group, along with his stutterers, were more inconsistent in this respect. Table V indicates that the stutterers and non-stutterers in the present study were rather similar, on the whole, with regard to the hand reversing. It is of special interest that so many in both groups (slightly more among the non-stutterers) reversed with neither hand, particularly when full reversals are considered. Such a performance is regarded by Van Riper as indicative of a relative lack of hemispherical dominance, and this condition he considers to be particularly characteristic of stutterers. Travis (2) and Orton (1) have been perhaps the chief exponents of such a theory. The theory is hardly supported by the findings presented in Table V, nor is it supported by the other data from the present study.

A further check on the validity or usefulness of the critical angle score was made, and the results are presented in Table VI. Using

TABLE VI

NUMBER OF VALID AND INVALID CRITICAL ANGLES POSSIBLE TO DETERMINE BY VAN RIPER METHOD

(angle at which first of two successive full reversals occurred)

Kinæsthetic Pattern

	No C.A.	Valid C.A.	Invalid-a[1]	Invalid-b[2]
Stutterers (N=98).....	54 (55.1%)	39 (39.8%)	4[3]	2
Non-stutterers (N=71) .	43 (60.6%)	24 (33.8%)	3	1

Visual Pattern

	No C.A.	Valid C.A.	Invalid-a[1]	Invalid-b[2]
Stutterers (N=98).....	44 (44.9%)	41 (40.6%)	0	13
Non-stutterers (N=71) .	45 (63.4%)	25 (35.2%)	0	1

[1] One or more non-reversed patterns drawn following critical angle reversals.

[2] One or more patterns partially, instead of fully, reversed following critical angle reversals.

[3] One of these is also to be tabulated under 'Invalid-b.'

Van Riper's definition of the critical angle, it was found that unless absence of two successive full reversals was taken to warrant a critical angle of 90 degrees, approximately half or more in each group could be given no critical angle score. Upwards of 40 percent could be given a thoroughly valid critical angle score. A few who scored critical angles, by making full reversals at two successive angles, invalidated them at subsequent angles by drawing normally oriented or only partially reversed patterns with the hand that had done the full reversing. (Van Riper did not have his subjects continue the test after establishing the critical angle, whereas in the present study the test was taken in full, patterns being drawn at every 10-degree angle up to the 90-degree angle, by every subject.) These data indicate that the test has what might be regarded as a rather low ceiling, particularly when scored in terms of the critical angle, as defined in Van Riper's (4) original study. The scoring method used in the present study makes for a somewhat higher ceiling, but the test appears to be intrinsically limited in its differentiating capacity. Many individuals go all the way through the test without reversing at all, and must all be scored alike, although it is reasonable to assume that a more discriminating test would serve to differentiate them from one another.

It is to be emphasized, however, that at the time this test was introduced by Van Riper, it was undoubtedly the most differentiating test of handedness that had so far been devised. Moreover, Van Riper advanced considerably the whole problem of the quantitative measurement of handedness.

V. Summary

Two groups of subjects, one of essentially unselected young adult stutterers, the other of essentially unselected young adult non-stutterers, were tested on Van Riper's angle board at all angles from 0 through 90 degrees, using the kinæsthetic and visual patterns. The testing procedure was similar to that employed by Van Riper (4). Scoring the productions on each pattern in terms of the number of principal horizontal movements made normally, the percentage of this number which were made by the right hand indicated no significant differences between stutterers and non-stutterers. Correlations between the scores on each pattern and between the pattern scores and those obtained on a hand usage questionnaire were low for both groups, with one possible exception. Stutterers and non-stutterers were also very similar in their scores on the hand usage questionnaire.

The performances were also scored in terms of the critical angle, as defined by Van Riper as the first of two successive angles at which full reversal of the drawn pattern occurs. The two groups of subjects were not definitely differentiated in terms of these critical angle scores, nor in terms of the hand, right or left, by which the reversing was done. Van Riper's (4) findings were compared with those from the present study and it would appear that his highly right-handed and highly left-handed subjects were quite extreme groups, while his ambidextrous subjects were fairly representative of non-stutterers generally. His conclusion that stutterers resemble ambidextrous non-stutterers would seem to mean, therefore, only that the average stutterer resembles the average non-stutterer on the angle board test. Further analysis of the data indicated that the test apparently fails to differentiate among individuals who do not reverse patterns with either hand, and that its discriminatory capacity is thus considerably limited, since many subjects, in the present study at least, did not reverse patterns.

VI. Conclusions

The hemispherical dominance theory of stuttering has been stated most elaborately by Travis (2); it has been set forth more concisely by Travis and Johnson (3). It postulates a relative lack of dominance of one cerebral hemisphere over the other, and on this basis an attempt is made to account particularly for such stuttering phenomena as the occasional relatively dyssynchronous functioning of the bilaterally paired structures involved in speech. Moreover, it is assumed that the relative extent of an individual's margin of hemispherical dominance (the degree to which one cerebral hemisphere exercises dominance over the other) is indicated by his handedness—*i.e.*, by the degree to which one hand is dominant in relation to the other. It is postulated, accordingly, that stutterers, having a relatively small margin of hemispherical dominance, tend to be ambidextrous, either innately or because of interference with the development of their 'natural' (usually left-handed) tendencies with regard to handedness.

Van Riper (4) attempted to obtain indirect evidence of the degree of hemispherical dominance in stuttering and non-stuttering subjects by means of a measure of the relative 'dominance' of one hand in relation to the other. For this purpose he constructed the angle board test used in the present study. He compared an essentially unselected group of stutterers with groups of non-stutterers, selected on the basis of hand usage data as highly right-handed, partly right-handed, ambidextrous, and highly left-handed. On the angle board his stutterers resembled the ambidextrous non-stutterers, and Van

Riper regarded this as evidence supporting the hemispherical dominance theory of stuttering, as sketched above.

It is not necessary here to examine the question as to the operational validity or meaningfulness of the assumptions involved in Van Riper's study and in the hemispherical dominance theory. It need be said only that if the hemispherical dominance theory of stuttering requires that differences be found between comparable groups of stutterers and non-stutterers on the basis of the angle board test and of hand usage data, the present study does not support that theory. The findings indicate, rather, that the average stutterer resembles the average non-stutterer in terms of the measures used in this study.

Another point is of incidental interest. An assumption which appears to be commonly held has been stated by Van Riper as follows: "The third basic assumption is that laterality is primarily quantitative in nature and is distributed according to a bimodal curve, the right-sided mode being very much the predominant one" (**4**, p. 372). The angle board scores obtained in the present study were not so distributed. These scores, dextrality quotients, represent the percentage of total achievement that is to be credited to the right hand, and thus express the degree of difference between the performances of the two hands. The distribution of these dextrality quotients, for both stutterers and non-stutterers, was unimodal and tended strongly to be normal in form. The means for both groups of subjects closely approximated 'ambidexterity,' indicating little relative difference between the performances of the two hands. After all, a bimodal distribution is to be expected if, but only if, handedness is defined to begin with as being of two types—if you look for right- and left-handedness you will find them. If, however, handedness is observed and measured in terms which permit scores to fall along a continuum —permit different individuals to be measured as different—the traditional right-left dichotomy disappears. The way in which handedness scores are distributed is seen to depend upon the type of measure employed. If it is true, as might reasonably be assumed, that the more differentiating the measure the more nearly will the obtained scores from a random population approximate a normal distribution, the theoretical significance of handedness, as traditionally considered, is to be thoroughly reëxamined. It might well be that theories relating right- and left-handedness, and ambidexterity, to various other conditions, such as stuttering, reading disabilities, etc., have been based in part upon an invalid assumption with regard to the nature of handedness. The low correlations between pairs of the various handedness tests used in the present study also raise a question as to the validity and meaningfulness of such theories, in that the correla-

tions indicate that as a general term 'handedness' is so vague as to be of little use for scientific purposes.

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THE EFFECT OF A DISCRIMINATIVE STIMULUS TRANSFERRED TO A PREVIOUSLY UNASSOCIATED RESPONSE

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One obstacle to the extension of conditioning principles to account for behavior outside of simple laboratory situations has been the apparently discrete nature of the correlation between a response and a conditioned stimulus established by the conditioning process. This difficulty can be overcome only in so far as different responses can be shown to co-vary in groups as functions of other variables. It is already well established (**2**) that different responses which have been reinforced in the presence of the same drive come to co-vary in strength as a function of that drive. The present paper reports an attempt to determine whether a group of responses conditioned to the same drive may not also tend to co-vary as a function of a stimulus to which only one response of the group has been specifically conditioned.

Operant or law-of-effect conditioning has been analyzed by Skinner (**2**) into two components: (1) the conditioning of a response to a drive by correlation of the response with subsequent reinforcement, and (2) the establishment of a discrimination in which any stimulus which is consistently present when the response is reinforced becomes an occasion for its emission (technically, a discriminative stimulus for the response).

The experiment to be described was designed to determine whether a stimulus which had been the basis for a discrimination in running upon an elevated straightaway would show a similar discriminative effect upon a lever-pressing response when first introduced into that situation.

PROCEDURE

Apparatus

The apparatus used for conditioning the lever-pressing response has been described in detail by Skinner (**2**) and Skinner and Heron (**3**). During a daily experimental period of one hour, each rat was enclosed in a light-proof and nearly sound-proof box containing a lever which could easily be depressed. This apparatus permitted either continuous or periodic reinforcement of the response with food pellets. Under the procedure of periodic reinforcement, the control clock was set to reinforce single responses to the lever every four minutes, intervening responses going unreinforced. A curve (number of responses *vs.* time) was recorded automatically for each rat.

The straightaway was a simple elevated runway, six feet long, with the starting platform at one end and the food box at the other. The discriminative stimulus used in both situations was a tone produced by phones attached to a 60 cycle A.C. transformer.

Subjects and Procedures

The subjects were 25 albino rats, 8 male and 17 female, taken from an unselected laboratory stock. All of them had been used in a simple laboratory demonstration involving a buzzer as a masking noise. After preliminary conditioning to the lever, they were given four days of periodic food reinforcement of the pressing response. Twenty of the rats were then transferred to the straightaway for the following procedures. The experimental group of 10 rats was given discriminative training with fifty percent of the runs accompanied by the tone and food. The order of reinforced and unreinforced trials was randomized. The control group of 10 rats received the tone on all trials although again only fifty percent of the runs were reinforced with food. The extent to which the first group learned the discrimination was measured in terms of the shorter time (in seconds) required for them to run the straightaway when the tone was sounding than when it was not. Each animal had 124 trials distributed over 22 days.

After completion of the straightaway training, the rats were all returned to the lever situation for two days of experimental extinction of the lever-pressing response. During these extinction trials the tone was on for alternate ten-minute periods. On the first day, the tone was turned on during the second, fourth, and sixth ten-minute periods; on the second, during the first, third, and fifth periods.

During all parts of the experiment the animals were allowed to eat for one hour immediately following the day's experimental period, that is, one hour out of twenty-four.

Results

It was apparent from the time scores on the straightaway that some of the rats with differential reinforcement had not established a discrimination during the trials allowed them [1] (see Table 1). Therefore, this group was divided near the mean so that 5 animals fell into each of the subgroups. The high scoring group was considered to have clearly demonstrated a discrimination. The criterion excluded all doubtful cases from the discrimination group, upon which subsequent comparisons were to be based.

Comparisons were then made among the extinction records of four groups of animals: Group I included the 5 rats which showed clear evidence of having learned the discrimination; Group II, the 5 rats which had apparently failed to learn the discrimination but had received discrimination training; Group III, 10 rats trained with the tone on all trials; and Group IV, 5 rats which had no training on the straightaway.

To take account of differences in motivation, each mean extinction curve was multiplied through by a constant chosen to correct for differences in rate of pressing under periodic reinforcement.

[1] For the last eleven days of training, the total running time during silent trials less the total time during tone trials for this group ranged from −82 to +201 seconds with a mean of 81.2 seconds. The range of comparable scores (total time during unreinforced trials less total time during reinforced trials) for the group trained with the tone on all trials was −343 to +158 with a mean of −26.7 seconds, indicating that the tone was exerting a significant effect upon the behavior of some of the animals receiving discriminative training.

TABLE 1

TOTAL TIME SCORES (TIME TO RUN STRAIGHTAWAY DURING UNREINFORCED TRIALS LESS TIME DURING REINFORCED TRIALS) FOR INDIVIDUAL RATS DURING THE LAST ELEVEN DAYS OF STRAIGHTAWAY TRAINING

Discrimination Trained		Non-discrimination Trained	
Rat	Score (in Seconds)	Rat	Score (in Seconds)
Group I		Group III	
1	+201	11	+158
2	+133	12	+60
3	+129	13	+30
4	+119	14	+13
5	+100	15	−1
		16	−9
Group II		17	−30
		18	−36
6	+96	19	−109
7	+68	20	−343
8	+44		
9	+4		
10	−82		
Mean (10 rats)	+81.2	Mean (10 rats)	−26.7

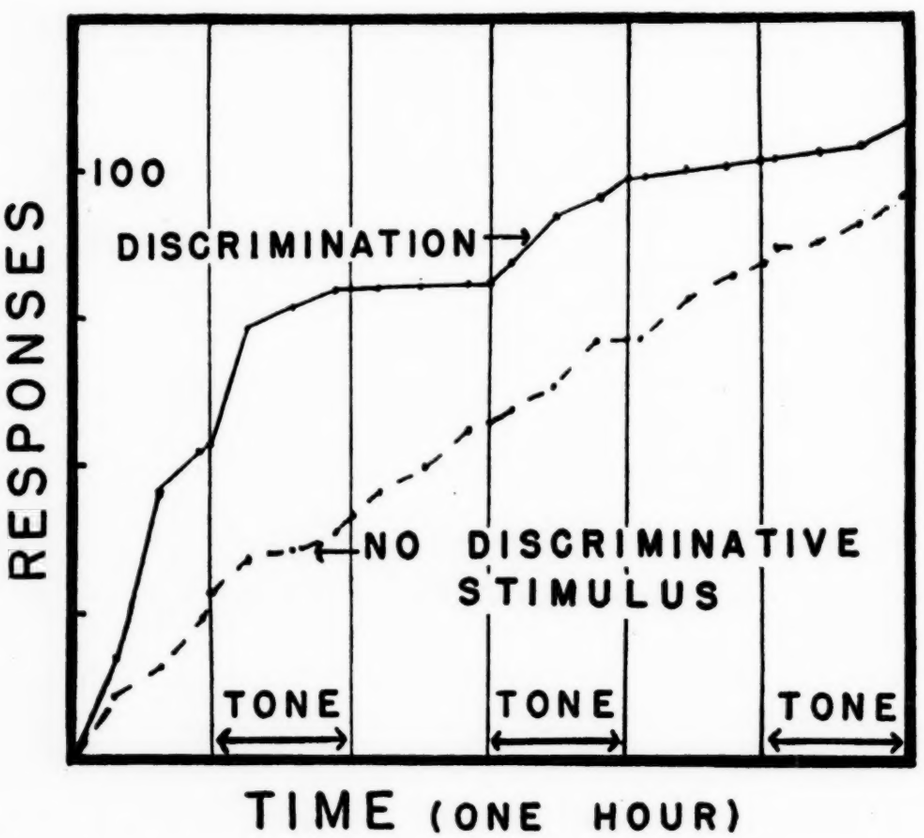

FIG. 1. Effects of the tone upon extinction curves of the lever-pressing response for the discrimination group and the group with non-discriminative training. The tone, which had been the discriminative stimulus in a straightaway situation for the discrimination group, exerts a discriminative effect upon the pressing response for that group, but not for the controls.

Fig. 1 shows the curve on the first day of extinction for Group I (the group that made the discrimination) and Group III (the group given non-discriminative training on the straightaway). The curve for the discrimination group deviates markedly from the typical negatively accelerated extinction curve approximated by Group III, exhibiting an increase in rate during the second ten-minute period, that is, the first period during which the tone was sounding, and a marked decrease in rate during the first subsequent silent period. This pattern is reproduced during the fourth and fifth periods to a somewhat lesser extent. It is apparent, therefore, that the effect of the discriminative stimulus on a new response is a strengthening of the response in its presence and a depression in strength of the response in its absence thereafter.

In Fig. 2, the comparison of the same curve for the discrimination group with the control group which had no straightaway training shows similar differences.

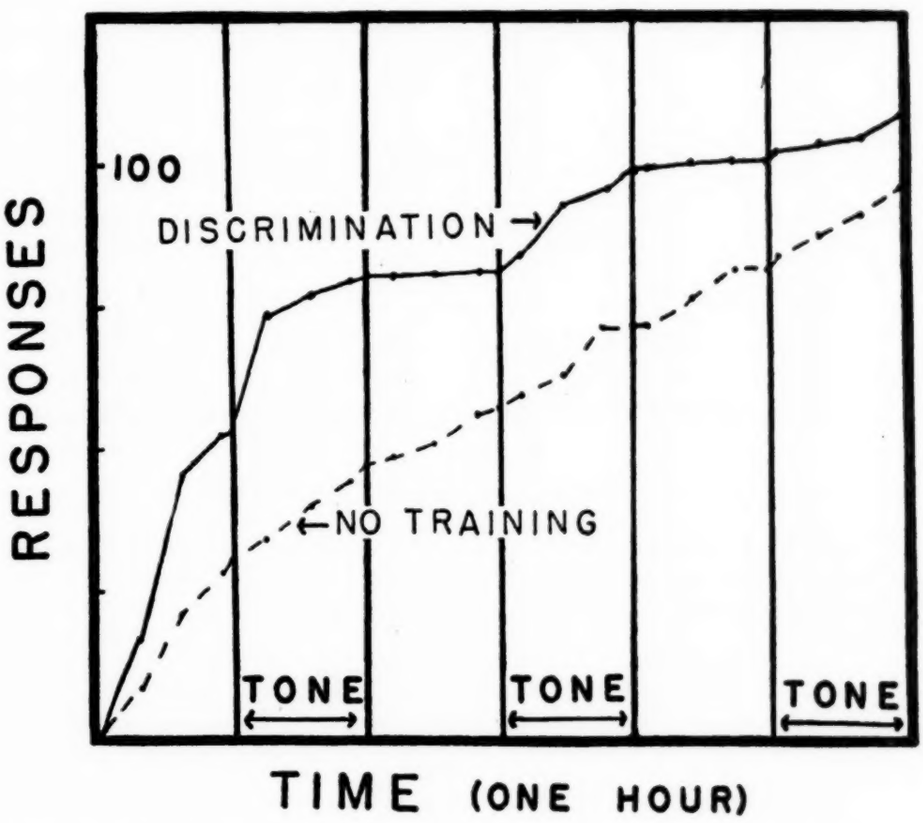

FIG. 2. Discriminative effect of the tone upon the extinction curve of the discrimination group compared with that of the group which received no straightaway training.

Even more marked differences are seen between Groups I and II, the two groups which had discriminative training (see Fig. 3). The curve for the group which failed to discriminate shows a slight decrease in rate during the first period in which the tone was present,

followed by a marked increase in rate during the subsequent silent period, with a repetition of the pattern during the fourth and fifth ten-minute periods. This trend is the reverse of that shown by the discrimination group, and suggests that the tone is acting as an inhibiting stimulus, which, opposing the discrimination, may account for the failure of this group on the straightaway.

Chi-square comparisons show that the differences between the mean extinction curve for the discrimination group and that for each

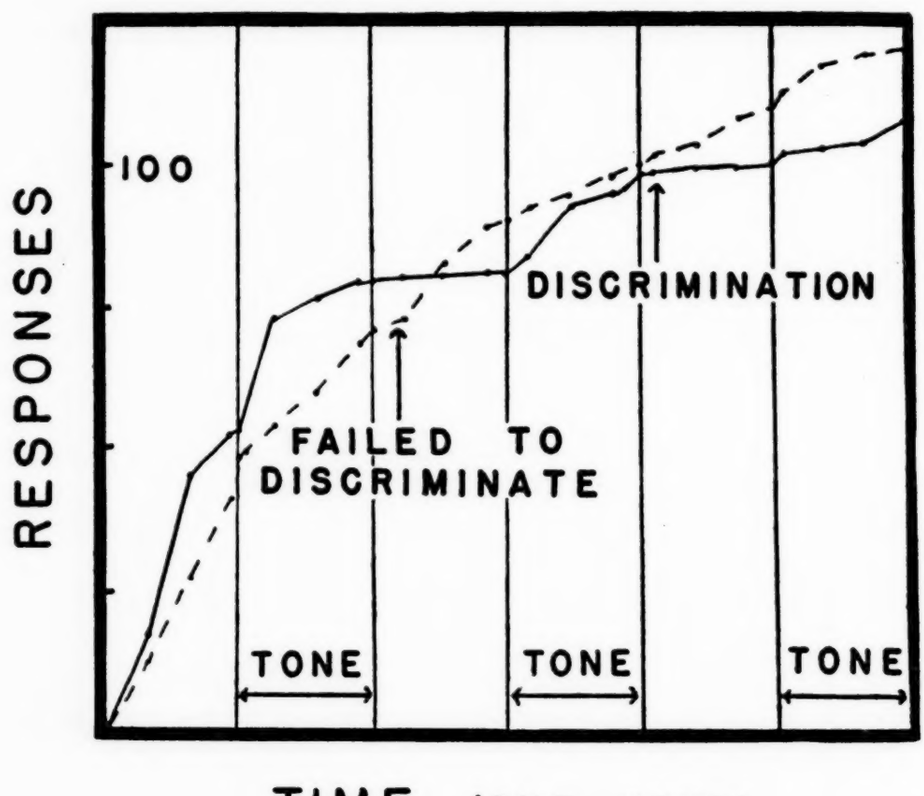

FIG. 3. Inhibitory influence of the tone upon the extinction curve of the group which failed the discrimination on the straightaway compared with the discriminative effect upon the curve of the discrimination group.

of the other three groups are statistically highly significant, while the control groups do not differ significantly among themselves (see Table 2). The same results are obtained when the comparisons are based on average extinction curves uncorrected for initial periodic rate.

In order to determine the periods in which the effect of the presence or absence of the discriminative stimulus was greatest, comparisons were made between the groups with respect to the percent of the total height of each rat's curve for the two days of extinction occurring within any single ten-minute interval. Student's *t*-ratios were used and were considered significant if they were of a magnitude which would be exceeded five times or less in 100 in a chance distribution.

At this level of significance, the experimental group responded significantly less often during the third ten-minute period (first silent period subsequent to the introduction of the tone) than any of the three control groups. The discrimination group emitted a significantly larger number of responses during the first ten-minute period than either the non-discrimination trained or untrained animals, while the group failing to make the discrimination responded significantly more

TABLE 2

PROBABILITIES THAT DIFFERENCES BETWEEN GROUP MEANS IN DISTRIBUTION OF RESPONSES DURING EXTINCTION AS LARGE AS THOSE OBSERVED WOULD ARISE BY CHANCE (DETERMINED BY THE CHI-SQUARE METHOD)

Day I				Day II			
Corrected for Periodic Rate							
Groups	II	III	IV	Groups	II	III	IV
I	<.001	.001	.002	I	.929	.836	.819
II		.396	.758	II		.797	.480
III			.601	III			.980
Uncorrected for Periodic Rate							
Groups	II	III	IV	Groups	II	III	IV
I	<.001	.007	.009	I	.935	.870	.945
II		.314	.724	II		.467	.352
III			.626	III			.964

than either the discrimination or non-discrimination trained groups during the fifth ten-minute interval. Remembering that part of the significance of these differences may be due to variability differences, we need F-tests to interpret them. Significantly lower variability with respect to percent of total extinction was found for the discrimination group as opposed to the three control groups during the third interval. Examination of the actual means and standard deviations of the groups indicates that the discrimination group was decidedly lower than any of the other three groups with respect to both mean rate of pressing and variability in rate of responding during this interval. We are forced then to attribute the significance to both rather than to the variability alone, indicating that the rate of responding for the entire group of rats making the discrimination was significantly depressed during the first silent period subsequent to the introduction of the buzzer.

During the intervals in which the discrimination group deviated most markedly from the controls, the rats which failed the discrimination showed significantly greater variability than any other

group. This high variability is probably due to the fact that this group included some rats which had made appreciable progress toward learning the straightaway discrimination as well as the complete failures.

The effect of the discriminative stimulus upon the behavior of an individual rat is shown in Fig. 4. The lower curve is that of a rat

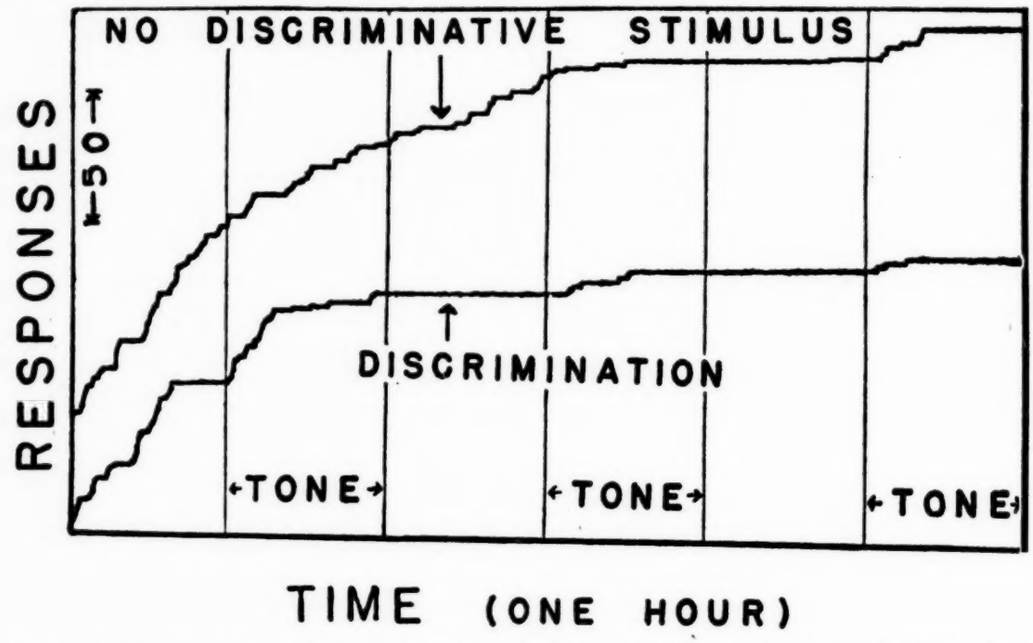

FIG. 4. Reproduced from photostatic copy of the extinction curves of two individual rats.

which had learned the discrimination. The record shows clearly the same trends noted in the mean curve for the group. The upper curve is that of a non-discrimination trained rat and represents a fairly typical extinction curve.

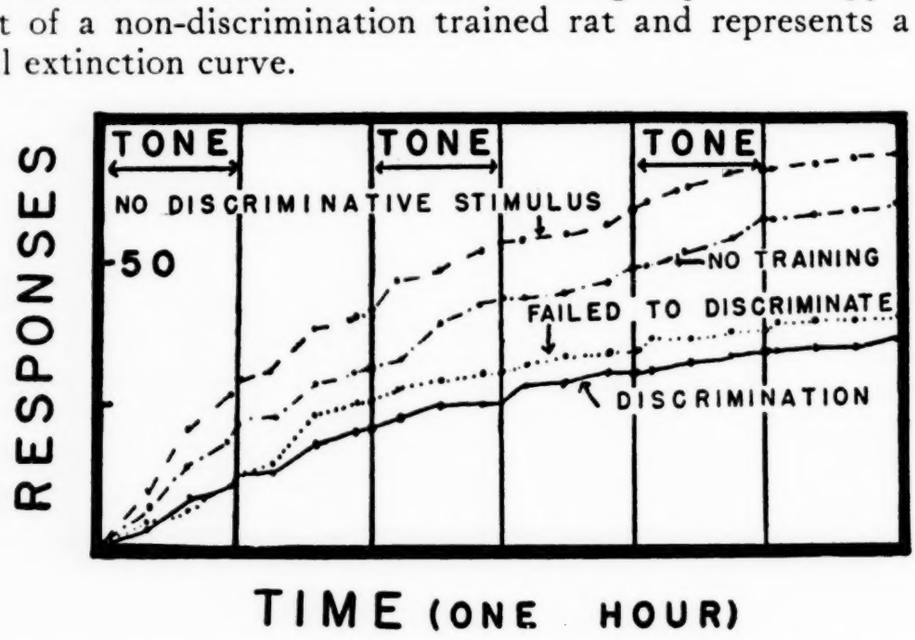

FIG. 5. Mean curves of the four groups on the second day of extinction. The discriminative effect of the tone has been extinguished, and the curve of the discrimination group is now similar in form to those of the controls.

On the second day of extinction the curve for the discrimination group did not differ significantly in form from those of the control groups (see Table 2 and Fig. 5) nor were significant differences found between the groups with respect to either silent periods or periods accompanied by tone. This indicates that the effect of the discriminative stimulus was extinguished although the response was not.

Differences were noted with respect to the height of the curves, the discrimination trained groups showing the lowest curves and the non-discrimination trained animals the highest, indicating that after the extinction of the effect of the discriminative stimulus, the new response still had some strength but not as much as would be expected had the discriminative stimulus not acted upon that response. Mean heights of extinction curves for the two days are given in Table 3,

TABLE 3

MEAN RATES OF LEVER-PRESSING DURING PERIODIC REINFORCEMENT AND DURING TWO DAYS OF EXTINCTION BY GROUPS

Group	Mean Daily Periodic Rate	Mean Height of Extinction Curves	
		Day I	Day II
I	502	86.44	28.46
II	878	134.60	55.24
III	634	117.55	66.79
IV	646	91.60	60.02

along with the mean periodic rate of each group. In comparison with the untrained and non-discrimination trained groups the discrimination trained groups exhibited a slightly higher extinction curve on the first day and a distinctly lower curve on the second day than would have been expected on the basis of initial periodic rate.

DISCUSSION

These results indicate that the tone which had become a discriminative stimulus for the running response produced a similar discriminative effect on the lever-pressing response when first introduced into that situation. The effect was comparable to that of a discriminative stimulus conditioned specifically to the pressing response as reported by Skinner (**2**, 177–201), but was less resistant to extinction. The generalized effect of the discrimination modified both the form and the total height (the reserve) of the extinction curve of the pressing response. Apparently the discriminative stimulus was effective in drawing out a number of responses during the first hour of extinction for the discrimination group which would not have been emitted until later under ordinary conditions of extinction, while the

generalized effect of the discrimination on the reserve of the pressing response was a reduction comparable to that produced by specific discrimination training on that response (**2**).

The extinction heights of the group which failed the discrimination resembled those of the discrimination group in being slightly higher than those of the untrained and non-discrimination trained groups on the first day and somewhat lower on the second day than would have been predicted from the initial periodic rates, probably because some of the animals which did not meet the criterion for inclusion in the discrimination group nevertheless made some progress toward learning the discrimination. The fact that the non-discrimination trained animals produced a slightly higher extinction curve than the untrained group suggests that periodic reinforcement in the straightaway situation was more effective than mere inactivity in maintaining the reserve of the pressing response over a period of time.

The behavior during extinction of some of the rats which failed to make the discrimination suggests that their failure to learn the discrimination was due to emotionality. These rats appeared to be more disturbed than the others by the tone when it was first introduced on the straightaway. Consistently long running times for these rats indicate that their emotional reaction to the straightaway situation never completely adapted out, and of course there was ample opportunity for the emotional response to become conditioned to the tone. The effect of an emotion has been shown by Estes and Skinner (**1**) to be a depression of the rate of pushing followed by a compensatory increase following the emotion. A comparable effect can be noted in the extinction curve for this group (Fig. 3). On the average these rats tended to stop pushing while the tone was sounding and to push at an unusually high rate during subsequent silent periods.

Summary

The experiment was designed to determine whether a stimulus which has characteristically preceded reinforcement of a response, and has therefore become the occasion for the occurrence of the response, will show a similar discriminative relation to other responses in the organism's repertoire which vary in strength with the same drive.

Twenty-five rats were first conditioned to press a lever for food reinforcement. Ten rats received discriminative training on a straightaway, the sound of a tone accompanying runs on which food was given, until five rats had shown evidence of a discrimination by running consistently faster when the tone was sounding. Ten control rats received identical training but with the tone sounding on all runs.

Five rats had no straightaway training. All groups were then returned to the lever-pressing situation for two one-hour periods of experimental extinction during which the tone was alternately on and off for ten-minute intervals.

The extinction curve for the rats which had formed a discrimination on the straightaway shows a distinct acceleration in rate of lever-pressing when the tone was sounding and a depression when it was not. Chi-square comparisons of this curve with those of all other groups show highly reliable differences.

(Manuscript received April 11, 1942)

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THE DISSOCIATION OF PUPILLARY CONDITIONED REFLEXES UNDER ERYTHROIDINE AND CURARE

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Introduction

In 1933, Harlow and Stagner, in an experimental effort to test the 'motor theory of learning,' failed to establish striated muscle CR in animals subjected to curare. These authors reported, however, that a pupillary conditioned reflex (CR) was established which persisted after recovery from the drug. They interpreted their results in favor of the 'motor theory' and concluded that "curare does not paralyze the central nervous system" (**9**, p. 293).

A few years after this report, it was shown by the present writer, in collaboration with Culler, that the isolated striated muscle could be conditioned in curarized animals (**6**). There was a cleavage, however, such that the normal- and drug-states were dissociated: normal learning was never manifested in the drug-state, and drug-state learning never persisted after recovery from the drug. Upon return to the condition in which the learning was first established, the CR spontaneously reappeared.

Preliminary electrical measurements were also made, in this investigation, of the sensitivity of the motor cortex and the spinal roots innervating the semitendinosus muscle. The results suggested the hypothesis that the dissociation or cleavage was due to a depression of the cortex such that the Curare-CR = Subcortical-CR whereas the Normal-CR = Cortical-CR. These preliminary electrical determinations were subsequently verified in a more exhaustive investigation (**2**), and conclusive functional confirmation of the hypothesis was procured by cortical ablations which prevented the curare-dissociation (**3**).

In this series of studies, which also demonstrated the inadequacy of the test of the motor theory of learning made by Harlow and

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Special aid from the Penrose Fund of the American Philosophical Society and the Elizabeth Thompson Science Fund is gratefully acknowledged. The erythroidine was generously supplied by Merck & Company, Rahway, New Jersey. Some of these results were reported at the meeting of the Western New York Section of the Society for Experimental Biology and Medicine, February 14, 1942.

Stagner, no attempt was made to observe any responses other than that of the isolated skeletal muscle. And there seemed to be no urgent reason for not accepting the evidence of Harlow and Stagner that the pupillary CR, unlike the striated muscle CR, persisted after recovery from the drug. It was suggested by the present writer that the pupillary CR might very well be mediated by subcortical pathways in both the normal- and drug-states, so that "curarization would, therefore, have no more effect upon pupillary conditioned reflexes than it does upon auditory CRs developed after extirpation of the cortical auditory areas" (3, p. 405).

Harlow in 1940 again reported that the pupillary CR persisted after recovery from the drug. In this latter publication, however, he admitted that "Harlow and Stagner's earlier assumption that the integrity of pupillary conditioned responses indicated that the central nervous system was not depressed is no longer tenable . . . [and] . . . the data from the curare experiments cannot be used to support the motor theory of learning" (8, p. 281).

From our own most recent investigations, the problem concerning the pupillary CR has once again been revived. With small dosage of curare and erythroidine, a CR involving the activity of the entire organism has been developed (4). As an integral component of the diffuse skeletal CR, there were autonomic concomitants which indicated that this pattern was affective in nature. In fact, whether or not it was possible to evoke generalized overt reactions, the isolated muscle contraction, or any striated muscle responses whatsoever, autonomic changes resulted from shock-stimulation and were susceptible to conditioning. Thus, increase in blood pressure was conditioned to a light stimulus (5). Since the pupillary responses are innervated via the autonomic nervous system, it was now certain that Harlow's results presented an unavoidable contradiction. It was at this point that the present experiment was initiated: a study of the pupillary CR in relation to the dissociation effected by curare and erythroidine.

Procedure

Conditional stimuli (CS) of several kinds were used in different combinations. The Light (L) was originally a 150-watt lamp, later alternated with a 250-watt spot-light containing a focusing lens and was placed about 1 foot from the animal's eye. The acoustic stimuli consisted of an ordinary door-bell (B), later supplanted by a pure tone (T) produced by a Western Electric 6-A audiometer. The unconditioned stimulus, shock (US), was applied momentarily to paw of fore- or hind-limb. In those cases in which the animals were first conditioned in the normal state to T followed by hearing tests in the stock-situation, US was always applied to forepaw. In subsequent tests with these animals in the drug-state, US was always applied to hind-paw. With naïve animals subjected to drug-tests at once, US was applied to either fore- or hind-paw.

L was used alone as CS in two situations: (*a*) L-4 secs., with momentary terminal US; (*b*) in later experiments, US was momentarily applied in the middle of this interval (end of 2 secs.). The latter technic made it possible to test for pupillary-dilation CR (PD-CR) *while the light was*

still on, and also had the added advantage of facilitating motion picture recording. In some tests, L was combined with T(L + T) or with B(L + B). In these cases, L was again presented for the usual 4 secs., during the last two secs. of which T or B was sounded. Here, US was applied with the simultaneous termination of both CS. When B or T was used alone as CS, it was presented for two secs. and terminated with momentary application of US.

A check on direct visual observation of the pupillary response was made with a pupillometer, constructed from a filar micrometer and object lens taken from a Gaertner telescope. The distance from object lens to eye piece was 11 inches and the distance from pupil to object lens 10 inches. The filar micrometer contained an etched scale and moveable hairline. By adjusting the latter to the edge of the pupil, quantitative variations in the pupillary diameter could be determined. The entire instrument was mounted on a rack and pinion for focusing purposes. For permanent records, 16 mm motion pictures were taken with both a Bell and Howell automatic load camera (f./1.5 lens) and a Ciné Kodak Special with an anastigmatic f./2.7, 2½ inch, telescope lens. Due to the intensity of the CS, no special lighting was necessary for the recording of the pupillary motion pictures, which were taken at the usual speed of 16 frames per second with supersensitive panchromatic, black and white, XX film.

Some observations were made on cats, but for the most part the research was done with dogs, ranging from 2 to 6 months in age and from 5 to 15 pounds in weight. At least 30 dogs were observed in the course of these experiments, typical protocols of 18 being specifically included in the present paper.

In an analysis of the neural basis of the pupillary-dilation CR (PD-CR) [see *Results, Section D*] the sympathetic innervation to the right eye was eliminated. Active dilation is maintained by the sympathetic component of the autonomic nervous system via the superior cervical ganglion. In the dog the nerve, passing from the latter to the dilator muscle of the pupil, is located along the trachea adjacent to the carotid artery. Under ether anesthesia, the trunk, after being carefully separated from the carotid artery, was cut completely and about one inch was removed to avoid regeneration. It was thus possible to determine the role of the sympathetic and parasympathetic components in the PD-CR.

The rest of the experimental procedure has been described in detail elsewhere (**3, 4, 5, 6**). Either raw curare or dihydro *B*-erythroidine hydrobromide was usually injected intravenously. Artificial respiration, when required, was maintained through tracheal insufflation by means of a Harvard respirator regulated to 22 strokes per minute. On one or two occasions, beta erythroidine hydrochloride has been used but it is not as effective as the newer dihydro derivative. Unless otherwise indicated, the drug-state was induced with dihydro *B*-erythroidine hydrobromide. It must be remembered that *this drug*, unlike curare, is *effective orally*, and proper precautions must be maintained.

Results

The data are divided into four sections.[1] (*A*) Initial observations of the pupillary responses during the study of generalized skeletal CR under curare and erythroidine (*cf.* **4**): animals *No. 1, 2, 3, 4, 5, 12,* and *13*. (*B*) Specific tests of pupillary responses in totally naïve animals: animals *No. R-19 R-20, R-23,* and *R-24*. (*C*) Same as (*B*), followed by training in the drug-state with motion picture recording: animals *No. R-1, R-6,* and *R-7*. (*D*) Study of the neural mechanism underlying the pupillary CR including motion picture recording: animals *No. R-2, R-8, R-9,* and *R-21*.

Section A

Nos. 1 and *2* were naïve animals. In preliminary normal tests with L + B, constriction (C) of pupil (P) to light (L) was followed by some dilation (D) to B.[2] Under the drug the normal

[1] The identification of the animals is the same as that used in previous reports in which some of the data were collected for other purposes, such as the study of generalized somatic CR (**4**) and blood pressure CR (**5**). To avoid confusion, no numbers have been duplicated, and hence *Nos. 6* to *11*, which are used elsewhere (**4**) and not included here, have been omitted. The same is true of the 'R' series.

[2] In view of the results previously published by others, it seems advisable to report the protocols in as great detail as space permits. In order to compensate for this, however, abbreviations will be employed to condense the material as much as possible. Also *cf. Procedure* for symbols used in indentifying the stimuli.

light-reflex to L, 'pin-point-constriction' (Pp-C) did not appear. Instead, the pupil remained somewhat dilated (½-C). In both animals, a diffuse CR to L + B was quickly established in the drug-state, and observations of P indicated that pupillary dilation (PD-CR) was a concomitant to the somatic conditioning. Tests with L-alone, in *No. 1* under the drug, indicated that the PD-CR was evoked by this stimulus without B: Initial ½-C was followed by D while L was still on. In both animals the diffuse- and PD-CR were repressed after recovery, at which time L evoked the usual light-reflex (Pp-C).

The following animals, *Nos. 3, 4,* and *5,* were first conditioned in the normal to fore-paw flexion CR to T, after which hearing tests were given in conjunction with another problem. After this study was completed, the present tests were made. In the drug-state the results were uniformly the same; normal CR was repressed, and PC ½ to L. In the case of *No. 3,* T had no effect on P, whereas, in *Nos. 4* and *5,* B produced some D of P. Diffuse CR was then established under the drug to L + B in *No. 3,* and to L-alone in *Nos. 4* and *5.*

Observations of the pupil during the training in the drug-state indicated clearly that PD-CR was part of the generalized somatic conditioning developed under the drug. In all three cases, the CR was completely repressed after recovery from the drug, and reappeared spontaneously when once again the drug state was reinstated. In *Nos. 3* and *4* the PD and diffuse CR first developed under erythroidine later appeared spontaneously when the drug-state was induced with curare. *Nos. 12* and *13,* as the last group of animals, were first conditioned to forepaw-flexion CR to T in the normal, after which tests of hearing were made. After this study was completed, the animals were used for the present purpose. In preliminary normal tests, normal light-reflex was evoked (Pp-C); soon after, under the drug the modified response occurred (½-C). PD to B was evoked in preliminary normal tests as well as in the drug-state. After this response to B was eliminated or nearly so with repeated trials, PD-CR to B with US reinforcement was then developed (*No. 12:* 0/2, 10/10; *No. 13:* 0/2, 3/5, 4/5). The PD-CR to B was of greater magnitude than the unconditioned response to this stimulus prior to training.

In *No. 12,* the drug-state was first induced with curare, during which the above conditioning scores occurred. The CR without further reinforcement carried over into a second curare-session, followed by a third drug-session induced with erythroidine. During intervening tests in the normal between these sessions, PD was evoked by B. During the next two sessions PD-CR to B was given further US reinforcement. The normal response to B was, however, getting progressively weaker. In the test in the normal before the 5th drug-session it was completely absent, and also failed to occur during tests after recovery from the 6th session. None the less, the drug-state PD-CR to B persisted and again carried over spontaneously, this time from the 5th to 6th drug-sessions.

It is clear that the response detected in the normal was simply an unconditioned response to B, and in no way connected with the conditioning-training in the drug-state. The drug-state CR maintained its strength and persisted from drug session to drug session, whereas the response to B in the normal finally disappeared. The same tendency was noted in *No. 13,* although the final tests after the drug-state training indicated that B still evoked some D of P. This normal response was not as marked as the CR developed in the drug-state.

Some observations on cats might also be properly mentioned at this point. In the normal, the usual light-reflex was produced by L. Under the drug before training, C to L was only ½. After training, diffuse CR to L was developed. Occasional tests of pupillary response clearly indicated that PD-CR had also been established, for now L produced ½-C followed by D before application of US. This experiment with cats was not elaborated, due to difficulties in procedure in inducing a number of successive drug-sessions.[3]

Section B

During the observation of the above animals, the pupillary CR (PD-CR) was noted to be composed, not only of continued dilation (D), but also of a 'disturbance' response (oscillating constriction-dilation sequence). Study of the pupillary response in naïve animals revealed that

[3] In dogs, artificial respiration was maintained by tracheal insufflation through a catheter inserted orally. In cats, it was necessary to perform a tracheotomy and introduce the air-stream through a tracheal cannula. Under these circumstances, the chances of infection were greatly increased if the tests were continued for more than two days or so. There being no operative intervention in dogs, tests could be and were extended over a period of months.

this latter phenomenon involved a component which was independent of the conditioning process. The following four animals were noted to give this typical 'hippus' response of the pupil prior to conditioning in the drug-state. The usual effect of the drug on pupillary reaction to L (½ C) and PD-CR were also noted.

No. R-19. On January 22, 1942, preliminary tests were made in the normal naïve animal. The usual light-reflex was evoked by L. L + T resulted in C of P to L (light reflex), followed by marked dilation to T (4096 cycles, 90 decibels). In the 1st drug-session, the same effect of L + T was noted. As with the earlier preliminary animals, normal light-reflex was now absent, PC only ½ and then D to T. Secondly, the pupil continued to oscillate between constriction and dilation. The rate of this hippus-like effect was within the limits of 10 to 30 oscillations per minute. It was not of great magnitude, changing the pupillary diameter about 1 mm.

In the 2nd drug-session on the same day, similar results were produced: PC ½ to L, with continued hippus. The latter phenomenon was then eliminated with large doses. After recovery, normal light-reflex (Pp-C) appeared.

No. R-20. This naïve animal was tested on January 23, 1942. The results noted in the previous animal were once again procured. In the normal, Pp-C to L. Under the drug, hippus was present and PC ½ to L. In this case, the initial dose of erythroidine was quite small, there being no noticeable muscular paralysis, and normal breathing was maintained. With L + T, again PC ½ to L and now D to T, hippus continuing uninterruptedly. After recovery, the normal light-reflex returned and the other effects disappeared. The same results were procured in a second session on the same day with even milder dosage.

No. R-23. This animal was tested on January 25, 1942, and was noted to be suffering from some respiratory difficulties; either a cold or incipient distemper. In the normal state, PC to Pp to L, and D to T. Under the drug, hippus was absent but L yielded usual drug-state response, ½ C, followed by D to T. After four trials of L + T (no US), L alone yielded ½ C followed by continued dilation during the last two seconds. This PD-CR to L (developed with paired combinations with T) was then extinguished following ten more trials of L-alone. The PD-CR was then reëstablished in the more conventional way (L-4 secs., with momentary US at middle of CS presentation) with the following results: 1/5 (2nd trial), 0/5, 10/10. The PD-CR consisted of initial ½ C to L followed by continuous D while L was still on. After recovery, only the normal light-reflex was present: *i.e.*, persistent Pp-C to L.

No. R-24. This naïve animal was tested on January 26, 1942. The usual responses were first noted in preliminary tests: L + T resulted in Pp-C to L, followed by dilation to T. Soon after, in the drug-state, PC ½ to L, followed by some D to T, hippus present throughout. With large supplementary doses, as with *No. R-19*, the hippus effect disappeared. This particular drug-session was quite prolonged; the total dosage was over 350 mgm., and the drug-session lasted for more than 5 hours. (Usually for single short sessions, 10 to 40 mgm. would be injected in 5 to 10 pound dogs, and the session lasted approximately ½ to 1 hour.) The following day the hippus effect returned in the 2nd drug-session induced with relatively small dosage. After recovery, the normal responses with L + T were noted.

In all cases, the reaction to L in the naïve animal was a sharp pupillary constriction (Pp-C) whereas in the drug-state only ½-C. In some cases, in the normal or under the drug, PD was not evoked by T. In no case was pupillary dilation produced by L in animals subjected to moderate dosage of the drug. In one or two cases the hippus effect was noted to be a direct concomitant of the pulsation rate of the Harvard respirator (22 strokes per minute). This in no way can be assumed as the sole cause of the hippus phenomenon, since it has been detected in animals subjected to doses so small that artificial respiration was not required.

Section C

No. R-1. The drug was injected after preliminary tests, on October 15, 1941, indicated a normal light-reflex in this naïve animal. The usual drug-state response of the naïve animal was noted, ½ C to L. This response and the subsequent development of the PD-CR to L were recorded with motion pictures. The summary of the training scores was as follows: 1/5 (5th trial), 5/5, 9/9 (US on 13/19). The CR consisted of strong PD with some concomitant diffuse responses since the dosage had been small and the animal was in the mild drug-state. Upon recovery the CR was repressed. The PD-CR reappeared spontaneously in the 2nd drug-session initiated an hour later.

No. R-6. Testing of this naïve animal was started on October 1, 1941, and within the next five days it had been subjected to nine drug-sessions. During this time, an analysis of the order of recovery of postural functions (without training) was first made, after which diffuse CR to T was established and recorded with motion pictures.

On October 14th in the normal state, the usual pupillary reflex to light was evoked. In the drug-session immediately following, the usual unconditioned response was noted, ½ C to L. A number of tests with L-alone were made in the process of first setting up the motion picture technic, following which a series of L-alone was then recorded. At first, the pupil tended to dilate a little as well as show some 'disturbance' response to the noise of the camera, but this was soon abolished. Hippus was not noted. Conditioning to L was then initiated for the first time and recorded simultaneously with motion pictures. A PD-CR was noted after the third training-trial, either as continued dilation or 'disturbance' CR. After additional training it was clearly noted that pupil C only 1/3 or 1/4 to L and then immediately dilated.

No. R-7. This naïve animal was subjected to 9 drug-sessions from October 8 to 10, 1941, inclusive. In the normal state, prior to the 1st session, the usual Pp-C to L was noted and T (1024 cycles and 2048 cycles, 90 db.) produced D of P. Under the drug, PC ½ to L. PD-CR was then established to L in this 1st session, the scores being 1/5, 3/5, 5/5, 3/5. On many of the latter responses, the pupil would contract only 1/3 or 1/4 after which D would occur. The PD-CR was developed well enough to carry over from session to session and always was repressed during intervening normalcy. The PD-CR was recorded with motion pictures in the 10th session. As a result of a number of unreinforced L-trials, the CR was soon extinguished and required further US-reinforcement to reinstate it.

Section D

No. R-2. On October 6th and 7th, this naïve animal was subjected to six drug-sessions during which a somatic CR to T was developed and recorded by motion picture technic. Right sympathectomy was performed on October 23rd. In the 7th session on October 24th, a somatic CR was evoked by the noise of the camera during the recording of the unconditioned responses to the first presentations of L. Through November 1st, 5 more drug-sessions were given, making a total of 12 drug periods.

The usual pupillary reactions to L in the normal and under the drug prior to training were noted. Actual training of PD-CR to L was begun in the 8th session, and the CR developed rapidly in the normal eye. The right eye, however, constricted to approximately the same size observed in the normal state; *i.e.*, 'pin-point' (Pp-C). The pupil of this eye also manifested either hippus, or else a 'disturbance' that was the result of the conditioning procedure. Some quantitative measurements were made which seemed to indicate that the 'disturbance' response was of greater magnitude than the hippus effect, and hence was a CR.

On November 1st, atropine was put in the right eye, and followed by the 12th session. The right pupil was now almost completely dilated and fixed, reacting neither to L nor US. CR in normal (left) eye had been extinguished, but with continued training, reappeared. After the introduction of atropine in the left eye, it, too, became quite dilated, only a thin 'rind' remaining. No CR could be detected, and US produced only a little dilation. Since the animal was in the mild drug-stage, while no PD-CR could be evinced, diffuse somatic conditioning was soon developed. The neural centers were thus obviously functioning.

No. R-8. This naïve animal was trained with L for PD-CR from start of first drug-session on October 10, 1941, which was continued in the next three sessions from October 13th–16th inclusive. In the 2nd session, with mild dosage, diffuse CR to L also developed. Carry over of PD-CR occurred spontaneously from 4th to 5th sessions, but was uniformly repressed during intervening normal periods. The usual pupillary responses were noted in both eyes: Pp-C in the normal state, with ½-C under the drug. PD-CR to L was extreme dilation following the initial ½-C.

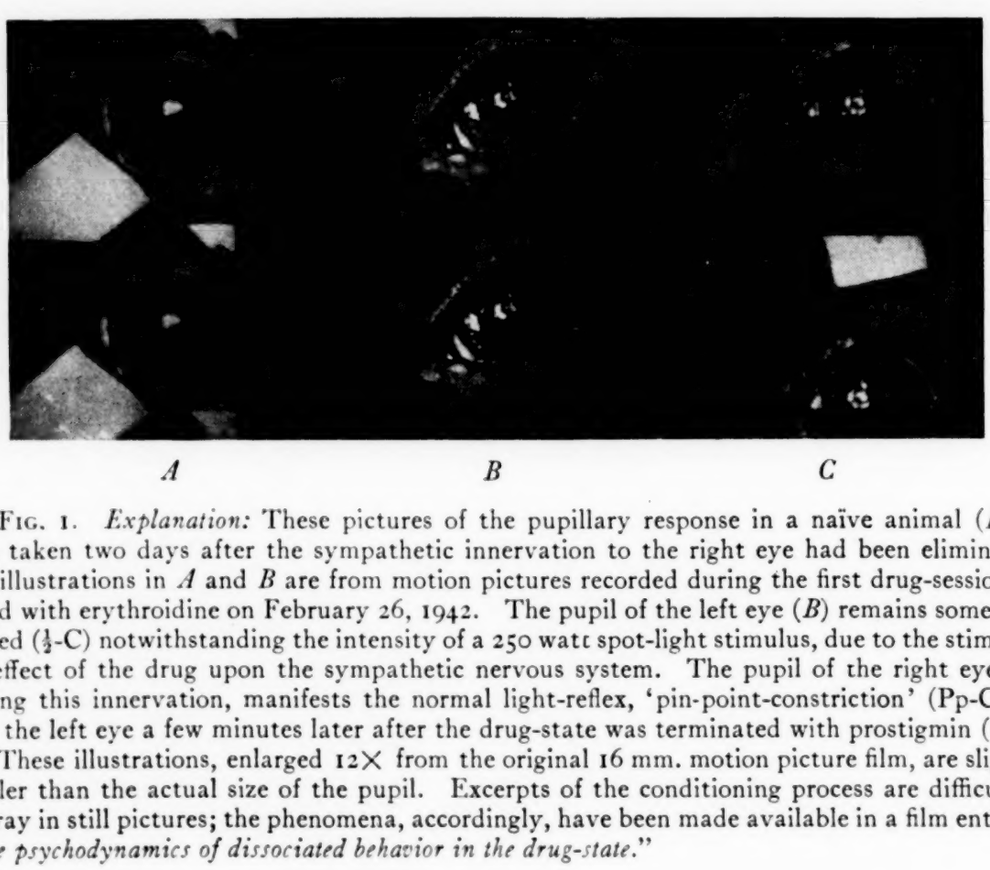
Right sympathectomy was performed on October 17th. Thereafter the pupil of the right eye showed Pp-C both in the normal and under the drug in the following 6th and final session on October 20th. In the drug-state, PD-CR was not present in this eye, whereas the left eye manifested the usual ½-C and the PD-CR as well. Hippus was not noticed at the beginning, although detected after the 10th training trial in the 1st session. As before, whether this effect was hippus or disturbance CR was hard to say. In view of its initial absence in this case, however, the disturbance response would seem to be due to conditioning.

No. R-9. Initially naïve, this animal was subjected to 3 drug-sessions on October 15, 1941. Motion pictures were taken of the unconditioned response to L in the 1st session, and during the actual conditioning in the 2nd session, and thereafter. The usual pupillary responses were noted: Pp-C of both eyes in the normal, but ½-C under the drug. After training, initial constriction was followed by dilation to L in both eyes. During the intervening normal periods the CR was repressed. Right sympathectomy was performed on October 23rd. In the 4th session on October 29th, the right eye maintained Pp-C under the drug, whereas the left eye showed ½-C with definite disturbance and dilation CR, carrying over from the previous session. Further training was then given, and the responses of both eyes were recorded with motion pictures. After the second shock-trial, the normal (left) eye remained even more dilated (about ¼-C), but the right eye was still constricted to Pp. Effect of atropine was as in the previous animal: both pupils became quite dilated and unresponsive to both L and US.

No. R-21. Right sympathectomy was performed in this naïve animal on January 23, 1942. On the next day, in the normal non-drugged state, both eyes responded with the normal light-reflex (Pp-C), the right eye becoming even more constricted than the left. The 1st drug-session was then induced with a very small dose of erythroidine, which produced no observable paralysis, normal breathing being maintained. A supplementary dose produced overt paralysis, the animal being unable to lift his head or raise self from prone position; normal breathing was still present. Another supplementary dose made it necessary to use artificial respiration. Further supplements were then given at spaced intervals, the total dosage being about 42 mgm. of erythroidine.

Tests of the pupillary response of this naïve animal were made between the successive injections. *With the very first small injection*, the normal eye manifested the drug-state response (½-C), whereas the right eye still showed Pp-C. Both eyes showed continued hippus. This clearly indicated that the latter was not simply a function of artificial respiration, since normal breathing was maintained until the 3rd injection. These drug-responses were noted throughout, since the total dosage was not enough to eliminate the hippus effect.

Conditioning to L was then initiated with the following scores: 0/10, 2/5 (?), 1/10, 5/10, 7/10, 9/10. (The score followed by the question mark is doubtful.) The unconditioned response to shock consisted of extreme dilation in the normal eye with concomitant diffuse skeletal struggle.



A *B* *C*

FIG. 1. *Explanation:* These pictures of the pupillary response in a naïve animal (*R-25*) were taken two days after the sympathetic innervation to the right eye had been eliminated. The illustrations in *A* and *B* are from motion pictures recorded during the first drug-session induced with erythroidine on February 26, 1942. The pupil of the left eye (*B*) remains somewhat dilated (½-C) notwithstanding the intensity of a 250 watt spot-light stimulus, due to the stimulating effect of the drug upon the sympathetic nervous system. The pupil of the right eye (*A*) lacking this innervation, manifests the normal light-reflex, 'pin-point-constriction' (Pp-C), as does the left eye a few minutes later after the drug-state was terminated with prostigmin (*C*).

These illustrations, enlarged 12× from the original 16 mm. motion picture film, are slightly smaller than the actual size of the pupil. Excerpts of the conditioning process are difficult to portray in still pictures; the phenomena, accordingly, have been made available in a film entitled, "*The psychodynamics of dissociated behavior in the drug-state.*"

The CR contained some skeletal reactions, as would be expected, *but the pupillary CR was confined to the normal eye possessing sympathetic innervation.* Towards the completion of the training, the normal eye failed to reach the usual drug ½-C to L. It was noted, on the last of the above training trials, that L yielded only about '¼-C' followed by dilation-CR. This must be attributed to the training to which the animal was subjected, since this effect occurred in naïve animals only after the injection of much larger doses. Both eyes showed continual hippus. The right eye, lacking sympathetic innervation, showed no dilation-CR whatsoever. From some pupillometer observations, it appeared that the hippus was increased in magnitude to a real 'disturbance' CR in the right eye. This problem however, still remains to be definitely settled. Whatever the answer to this specific question, the following are completely unequivocal. After recovery from this first drug-session, both eyes showed the usual light-reflex (the right showing more constriction). The CR was completely repressed, neither eye showing any symptom of pupillary disturbance or dilation-CR. The striate musculature remained completely relaxed, the animal completely indifferent to the test situation.

On the same day, when a second drug-state was induced, the pupillary CR reappeared in the left (normal) eye, whereas the right eye manifested only the disturbance response. Both eyes again showed hippus. We thus see that the PD-CR was a function of the drug-state, was repressed upon recovery and, with sufficient training, reappeared spontaneously when the drug-state was reinstated.

The difference in reaction between normal and sympathectomized eyes was uniformly the same for all animals. The operated eye constricted to almost normal size under the drug; the normal eye showed the usual ½-C in the drug-state (*cf.* Fig. 1). After conditioning, the dilation-CR to L appeared in the normal eye. The right eye manifested hippus or 'disturbance' CR but in no case manifested the extreme dilation CR. These reactions occurred either by direct stimulation or indirect (stimulating the other eye) consensual reflex.

Discussion

In the dissociated drug-state, induced with either erythroidine or curare, a pupillary dilation conditioned reflex (PD-CR) was established. After a sufficient number of paired training-combinations of light with shock, the initial ½-C was now followed by marked dilation or 'disturbance' (dilation-constriction) CR while the light was still on. There is some doubt concerning the 'disturbance' CR. The reason for this lies in the phenomenon of hippus which has been detected in a number of animals before training. Occasional quantitative tests indicated that the pupillary 'disturbance' CR in the drug-state may depend upon the hippus phenomenon, but that it is of greater magnitude. The disturbance oscillations, too, have been noted after conditioning in some cases in which the hippus effect was initially absent. But exact test of this specific question must await more extended quantitative measurements.[4]

The marked pupillary dilation CR, on the other hand, was qualitatively different from the hippus phenomenon, and unequivocally

[4] Pupillometer measurements and motion picture recording have not been used completely in the present study. They have been employed sufficiently to show the practicality and usefulness of the method, as well as in establishing the validity of the PD-CR. The speed of conditioning, the extinction process, maximum size of CR and other related problems are important in their own right. These problems, however, were neglected, in order to establish the main purpose of the present study: the validity of the PD-CR and its suppression after recovery from the drug-state. For this reason, such problems as the relation of hippus to the 'disturbance' CR have been relatively untouched.

the result of conditioning-training. This CR (extreme dilation) was due to active stimulation of the sympathetic nervous system and not to inhibition of the parasympathetic component, since it disappeared or failed to develop when sympathetic innervation was eliminated. On the other hand the disturbance CR, like hippus, was present after this operative intervention. If the disturbance CR was truly the result of the conditioning process, then it was dependent upon cyclic parasympathetic inhibition, as was hippus. This would mean that the entire autonomic nervous system was involved in the pupillary CR, extreme dilation being a function of sympathetic stimulation, whereas the disturbance response was due to inhibition of the parasympathetic mechanism.

The PD-CR was readily subject to extinction. In several cases in which motion picture records were taken, extinction resulted after a number of trials with Light-alone and further reinforcement was necessary to reinstate it. It is our impression that the pupillary CR was not as stable as the diffuse skeletal CR and was more susceptible to extinction.

The PD-CR to light has never been detected after recovery from the drug-state. While some of the data procured with bell as CS are unreliable, the results with Light-stimulus are completely unequivocal. In every single case the pupil, after recovery, manifested the normal light-reflex (maintained constriction) until the light ceased. This observation has been repeated time and again in animals tested for as many as 10 to 15 drug-sessions. In some cases, literally hundreds of training trials were given in a number of successive drug-sessions, sometimes spaced over a period of weeks. In not a single instance has the pupillary response in subsequent normal periods been affected by previous training in the drug-state. Furthermore, if sufficient training had been given, the PD-CR would reappear spontaneously when the animal was reintroduced into the drug-state. There was no difference between curare and erythroidine, since the CR established with one drug would appear when the drug-state was subsequently produced with the other drug.

Some apparent exceptions, which in no way disturb the above generalization, simply emphasize the extreme care which must be used in observing the action of this delicately adjusted mechanism. Occasional marked dilation or disturbance, for example, occurred as the result of some startling stimulus. Sudden uncontrolled noises or movements on the part of the experimenter, head- and eye-movements on the part of the animal, all would change the size of the pupil. These effects, of course, occur in naïve animals and in no way are attributable to the conditioning process. With proper controls, however, the results after recovery were uniformly negative. A pupillary

CR established under the drug has never been detected in the normal state.

In all other respects as well, the animal after recovery acted like a naïve subject. No trace of the drug-state experiences was evidenced, the animal remaining entirely indifferent to both the conditional stimuli and the experimental situation [*cf.* (**4**, **5**) for elaboration of this point]. Since the CR developed in the drug-state was a complex 'excitement' pattern composed of skeletal and autonomic responses, we should not expect to find an avulsion between one component, pupillary CR, and the other symptoms of affective behavior. We cannot concur, therefore, with the conclusion that "curare produces different influences upon the various components of a total conditioned response pattern" (**8**, p. 278).

In the drug-state, in naïve animals, the normal light-reflex was disturbed so that the pupil remained somewhat dilated ($\frac{1}{2}$-C). Sometimes, there also occurred a hippus-like effect, "a rapid constriction and dilation of unknown origin" (**7**, p. 124). The former phenomenon was due to active stimulation of the sympathetic and the latter to cyclic inhibition of the parasympathetic component of the autonomic nervous system. As a consequence, normal pupillary balance was disturbed and pupillary dilation was even more readily produced in the drug-state than in the normal animal. This unconditioned response was as readily evoked by intense stimuli after many drug-sessions as at the beginning. So marked was this reaction, that it was possible to establish, in a few trials, pupillary dilation CR to light, using tone as the unconditioned stimulus.[5]

From the present data it would appear that the pupillary CR to bell which, according to Harlow, crosses the boundary of the dissociation between the normal- and drug-states, consisted of unconditioned and not learned responses. In one experiment (No. 3), Harlow attempted to determine the effect of extinction-trials given in the drug-state after learning had been established in normal animals. The cats, first trained to leap from the grid at the sound of bell, were then subjected to the drug and given a number of trials of bell without

[5] Pupillary CR to bell and tone with shock as US were also developed. The pupillary dilation CR to bell or tone was greater than the unconditioned response to these stimuli. In these cases, likewise, it was equally certain that the pupillary CR was repressed after recovery from the drug. That is, the dilation to bell or tone after recovery appeared to be no different, in magnitude or quality, from the response observed in the untrained animal.

It was for these reasons that light was substituted in place of sound as CS, in the critical test of the present problem. With a rare exception 'physiological hippus' (**1**, p. 327), light was the ideal stimulus. It produced a rapid light-reflex in the normal state (Pp-C) or, under the drug, $\frac{1}{2}$-C. Unlike sound it did not produce dilation. To this one qualification must be noted. With extremely large doses, the pupillary response was very sluggish; contraction to light was slow and weak followed by dilation. With even still larger doses the light reflex was completely abolished. This last effect occurs in humans before complete muscular paralysis sets in (**10**).

shock. After recovery the flight CR was still undisturbed. In conjunction with this experiment, another test was made in the drug-state:

> "*Experiment* 4. . . . Concurrently with Experiment 3, the conditioned pupillary response to bell was extinguished by the unreinforced stimulations. The effects were noticeable after about 100 repetitions, but about 150 were required to extinguish it completely" (**9**, p. 289f).

Since shock was the unconditioned stimulus during the initial training in the normal state, one may properly assume a pupillary CR was developed. There is every likelihood, however, that the pupillary response detected under the drug was an unconditioned reaction to bell rather than the persistence of the normal CR. The fact that a large number of trials (100–150) were required to 'extinguish' it, contrary to the present findings (10–20), supports this interpretation. Apparently no tests of the pupillary response were made after recovery, but it is equally certain that the original pupillary dilation CR reappeared as the animals jumped in flight and fright at the sound of the bell in the post drug-state tests.

The probable facts are: (1) pupillary dilation CR to bell was initially developed concomitantly with the flight CR in the normal training. (2) The normal flight and pupillary CR were repressed in the drug-state. The pupillary response detected at this time was unconditioned in nature. (3) After recovery, pupillary and flight CR reappeared. If these interpretations be correct, the results of Harlow's experiments support the present findings. From the present evidence, it is concluded that pupillary CRs are established in the drug-state as part of an entire pattern, skeletal and autonomic, which remains dissociated from the normal experiences.

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CRITICAL CONDITIONS INFLUENCING SENSORY CONDITIONING [1]

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In a previous paper (1) the writer described conditions under which 80 percent of his subjects reported the occurrence of a tone which was not objectively presented. In an earlier attempt to produce an artificial synesthesia, Kelley (3) was unable to obtain a single case in which his subjects reported the occurrence of a color stimulus when the stimulus was not presented, although he gave from 5 to 16 times as many training trials as the writer found necessary. The techniques of Kelley and the writer were similar in that both involved sensory conditioning or the pairing of a signal stimulus with the one whose occurrence was to be reported. They differed in a number of respects, any one or several of which might conceivably account for the disparity in results. The present investigation is an experimental study of the effects of two of the differences.

Kelley used two procedures. The first paired the eight tones of an octave with eight colors which were projected on a screen simultaneously with the tones. An obvious defect in this procedure (pointed out by Kelley) was that many of the subjects, even after 1000 pairings, could not name correctly the colors paired with the respective tones, which suggests that the tones were not sufficiently discriminable. In Kelley's second procedure, he paired only one tone and color for each subject. Tone and color were presented simultaneously for 9 seconds, with 3 seconds between trials. In test trials, the tone or signal stimulus was presented alone.

In the writer's experiment a tone was used as the stimulus to be reported and a light as a signal or conditioned stimulus. The tone came very gradually above threshold from 2 to 6 seconds after the onset of the light and also terminated gradually. Kelley's projected color, which corresponded in function to the tone, had a sudden onset considerably above threshold, appeared simultaneously with the signal tone, and terminated suddenly. The effect of this difference in method of presentation of the stimulus was investigated in the present study.

[1] The experiment described in this paper was performed at Stanford University, in the Department of Psychology. The paper has been accepted and approved by the Stanford University Committee on Psychical Research as Communication No. 12 from the Psychical Research Laboratory.

Another variable investigated is the effect on the subjects' responses ascribable to information concerning the purpose of the experiment and to the occurrence of test trials in which the stimulus to be reported was omitted. In Kelley's experiment, information regarding the true purpose of the study and the nature of the test trials was given to the subjects. In the writer's earlier experiments the subjects were told that the procedure was a test of auditory acuity and were not informed about test trials, that is, trials in which the tone was omitted.

Procedure

The procedure differed from that of the writer's earlier investigations (1, 2) in that the experiment was conducted in a sound-insulated room, the subjects were tested in small groups rather than singly, and a temporal conditioning procedure was used. A General Radio beat frequency oscillator was used as in the previous experiment to produce the 1000-cycle tone which was the stimulus to be reported (unconditioned stimulus).

The experimenter and subjects were seated at tables facing the wall in the experimental room. On the table before each subject was a noiseless mercury-switch key which was connected with a small signal light on the experimenter's table. A cloth screen suspended in the form of a triangular booth surrounded each subject from above his head to table-level, effectively isolating him visually from the others.

Subjects were obtained from psychology classes and were run in groups of 5 or less. The number of groups containing 1, 2, 3, 4, and 5 subjects was 1, 3, 6, 10, and 15 respectively. Results for one subject were omitted when it was found that he had previously taken part in a similar experiment. Three experimental groups were used.

Procedure for Group I.—Group I was run under conditions similar to those found in the writer's previous experiment to be favorable to the report of the tone when it was not presented. This group contained 49 subjects, 27 males and 22 females. The subjects were seated at the tables and asked to operate the signal key as their names were called. This served as a check on the condition of the apparatus and the ability of the subjects to operate the key. The cloth screen was then drawn around each subject, the 1000-cycle tone was presented at about 30 decibels above threshold, and the following instructions were read:

> "The tone I have just turned on is the one I am going to use in this experiment. What I want to do is to determine how faint a tone you can hear. What you are to do is to press the key as soon as you hear the tone, hold it down as long as you hear it, and let it up when you do not hear it any longer. Please pay very close attention because the tone is very faint most of the time. Remember, when you are holding down the key, that means that you are hearing the tone. Please keep your fingers off the key when you do not hear the tone, otherwise you may press it by mistake. Now we will begin."

The instructions were followed by a 5-minute pre-test period in which no tones were presented. The number of times each subject pressed his key within the 5-minute period was recorded. The pre-test period was followed immediately by 30 training trials in which a temporal conditioning procedure was used. At regular 30-second intervals the tone was turned on at an intensity below threshold and was increased at the rate of 2 db./sec. until all subjects had indicated by pressing their keys that they heard it. The intensity of the tone was then decreased at the same rate until each subject had released his key, at which time the tone was terminated. Responses of the subjects between trials when no tones were being presented were recorded except for 10 subjects in Groups I and II (see *note* appended to Table 1).

The 30th trial was followed immediately by a 5-minute post-test period similar to the pre-test in which no stimuli were presented. The number of responses given during the post-test period was recorded.

Procedure for Group II.—This group contained 47 subjects, 27 males and 20 females. The procedure was identical with that for Group I with the exception of the method of presentation of the tone during the training trials. Here the tone was presented in a manner similar to Kelley's

presentation of the color stimulus in both of his experiments. The onset and termination were sudden and the intensity throughout was considerably above threshold. The tone was presented at 10, 20, or 30 decibels above threshold in random order in order to preserve as much as possible the resemblance of the procedure to that of an auditory acuity test. The duration of the tone was 5 seconds.

Procedure for Group III.—This group contained 43 subjects, 26 males and 17 females. The procedure was identical with that for Group I to the end of the 30-trial training period. Immediately thereafter the subjects were informed that the experiment was designed to investigate hallucinations and that in order to determine whether hallucinations were being produced, a test period would follow in which no tone would be presented. They were then requested to listen just as they had been listening and to press the key if they heard the tone or what they thought was the tone. Any questions were answered briefly, after which the 5-minute post-test period was given and responses were recorded.

Summary of procedures specific to each group:

Group I: Trained with gradual onset of tone. Given no information as to the nature of the experiment or the occurrence of test period.

Group II: Trained with sudden onset of tone. Given no information as to the nature of the experiment or the occurrence of test period.

Group III: Trained with gradual onset of tone. Informed after training of the nature of the experiment and of the occurrence of test period in which no tone was presented.

Results

Data to be considered are the number and percent of subjects in each group pressing the key at times when the tone was not present. These results are given for the pre-tests, the training periods, and the post-tests in Table 1. Significance of inter-group differences based on the standard errors of proportions is presented in Table 2.

Since in the pre-test the conditions were the same for all three groups, the percentage of subjects indicating that they heard the tone during the pre-test may serve as an index for comparing groups with regard to the initial tendency to press the key when the tone was not

TABLE 1

Showing for the pre-test, training, and post-test periods the number and percent of subjects in the three groups who pressed the signal key at least once when no tone was presented.

	Group I	Group II	Group III
Pre-test			
No. subjects in group	49	47	43
Subjects responding	10	8	6
Percent responding	20.4	17.0	14.0
Training			
No. subjects*	39	37	43
Subjects responding	17	5	21
Percent responding	43.6	13.5	48.8
Post-test			
No. subjects in group	49	47	43
Subjects responding	21	4	15
Percent responding	42.9	8.5	34.9

* No record was kept of hallucinatory responses during the training period for the first ten subjects in Groups I and II.

TABLE 2

SIGNIFICANCE OF INTER-GROUP DIFFERENCES BASED ON THE STANDARD ERRORS OF PROPORTIONS

	Groups Compared	$\frac{\text{Diff.}}{\sigma \text{ Diff.}}$
Pre-test	I vs. II	0.52
	I vs. III	1.10
	II vs. III	0.58
Training	I vs. II	3.22
	I vs. III	0.89
	II vs. III	4.12
Post-test	I vs. II	4.29
	I vs. III	1.29
	II vs. III	3.01

presented. There were no significant inter-group differences in this measure.

The proportion of subjects giving one or more hallucinatory responses between presentations of the tone during the training period is significantly greater in both Groups I and III, to which the tone was presented with gradual onset, than in Group II to which the tone was presented with sudden onset. The difference between Groups I and III (trained under similar conditions) was not significant.

The conditions preceding the post-test period differed for Groups I and II as described in the procedure section. The percentage of subjects giving one or more responses in the post-test was significantly less for Group II, which was trained with sudden onset of the tone.

In the post-test period, the difference in number of subjects giving one or more responses in Groups I and III was not statistically significant. These two groups were given the same training, but Group III was told the purpose of the experiment (to produce hallucinations) just prior to the post-test, while Group I was not.

The statistically significant difference in the post-test results between Groups II and III is not interpretable since two variables are involved.

DISCUSSION

The above results show that when subjects are given a series of tones at regular intervals, the proportion reporting the occurrence of the tone when it is not being presented is significantly less when the tones are presented with sudden onset and termination than when they are presented with gradual onset and termination. These two methods of presentation of the tone represent one difference between earlier experiments of the writer (**1**, **2**) which obtained evidence of hallucinations produced by sensory conditioning and experiments by Kelley (**3**) which did not do so. It would appear that one explanation of the failure of Kelley's subjects to report hallucinatory color is that

he presented his unconditioned stimuli under conditions of sudden onset and termination.

Incidental observations in exploratory work with different stimuli suggested that the conditions of sudden onset serve to train the subject in discriminating between the occurrence and non-occurrence of the stimulus. This observation is supported in the present experiment by the fact that in Group II (see Table 1) a smaller proportion of subjects gave false responses in the post-test (after 30 presentations of the tone with sudden onset) than in the pre-test. The difference is not statistically significant, however.

A second difference between Kelley's procedure and that of the writer's earlier experiments is represented by the procedures of Groups I and III. Instructing the subjects concerning the nature of the experiment resulted in a slight but insignificant reduction in the proportion reporting the perception of the tone during the post-test period. These results are in accord with those of an earlier experiment (**2**) in which 16 subjects who had reported hallucinatory tones during a series of 20 test trials were told that no tones would be presented on subsequent test trials. In the following 10 test trials, 15 of these 16 subjects reported the occurrence of the tone. These results suggest that the insight of Kelley's subjects into the purpose of the experiment and the occurrence of test trials was not an important factor in producing his negative results.

One aspect in which Kelley's experimental conditions differed from those of the writer, namely that of the nature of the stimulus to be reported, has not been examined. It is entirely possible that visual perceptions, which Kelley used throughout his experiment, are not as susceptible to conditioning as are auditory perceptions. This possibility can be examined in a further experiment in which an attempt is made to condition a visual perception under conditions including gradual onset and termination of the stimulus.

Summary

Two differences in procedure between an unsuccessful attempt by E. L. Kelley to obtain hallucinations (chromesthesia) by a conditioning procedure and the writer's previous successful attempts were examined experimentally. It was found that training subjects by presenting a tone at regular intervals with a gradual onset and termination produced a significantly greater proportion of subjects who reported the tone when it was not present than did similar training in which the tone was presented with sudden onset and termination. A comparison of the effect of telling the subjects the purpose of the experiment and that the tone would not be presented during a test

period with the effect of not telling them did not show a significant difference in the proportion of subjects falsely reporting the tone.

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VARIABILITY OF ATTACK IN MASSED AND DISTRIBUTED PRACTICE *

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Introduction

This experiment is the second in a sequence of studies in which the differential effects of massed and distributed practice have been analyzed. In the first experiment (**5**) it was noted that rats in a 12-unit multiple-T maze consistently made more errors on the second of two daily trials than on the first. This was due to the fact that on the first trial following a 24 hour interval, the rats tended to repeat the responses of the last previous trials. On the second trial (massed practice) of each day, a greater variability in behavior occurred resulting in a larger number of new errors than on the first trial of that day.

Several other investigators have been interested in this phenomenon of increased variability of behavior following the initial trial. So far as this writer is aware, these other investigators have not yet applied the results of their analyses directly to some specific form of learning behavior. Their efforts have been directed at trying to account for the phenomenon, *per se*. Reference is made to the several studies by Dennis (**4**) and his co-workers; Dennis, Henneman, and Varner (**2**), Dennis and Sollenberger (**3**), Wingfield and Dennis (**9**). More recently Heathers (**7**) has extended their technique and procedure and has formulated, within the framework of conditioning theory, a general principle of 'performance decrement' to account for this variability of response following the initial trial and after varying periods of delay.

The present experiment differs from these studies in that we are accepting this variability in massed practice as a fact rather than trying to explain it. Our problem is to extend the application of this phenomenon into a specific learning situation.

The results of our own first experiment and these other studies make possible the following conclusion: Distributed practice tends to produce a fixation of response while massed practice results in greater variability of behavior. The generality of this principle is limited, however, by the unique condition of the first experiment in which

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there was only one distributed and one massed trial on each day. And so for the massed practice condition, especially, we are dealing with only the initial effect of this kind of practice. The changes in behavior that occur with successive immediate trials can only be inferred. Considering this limitation we can postulate that distributed and massed practice will show a differential effect in those learn-

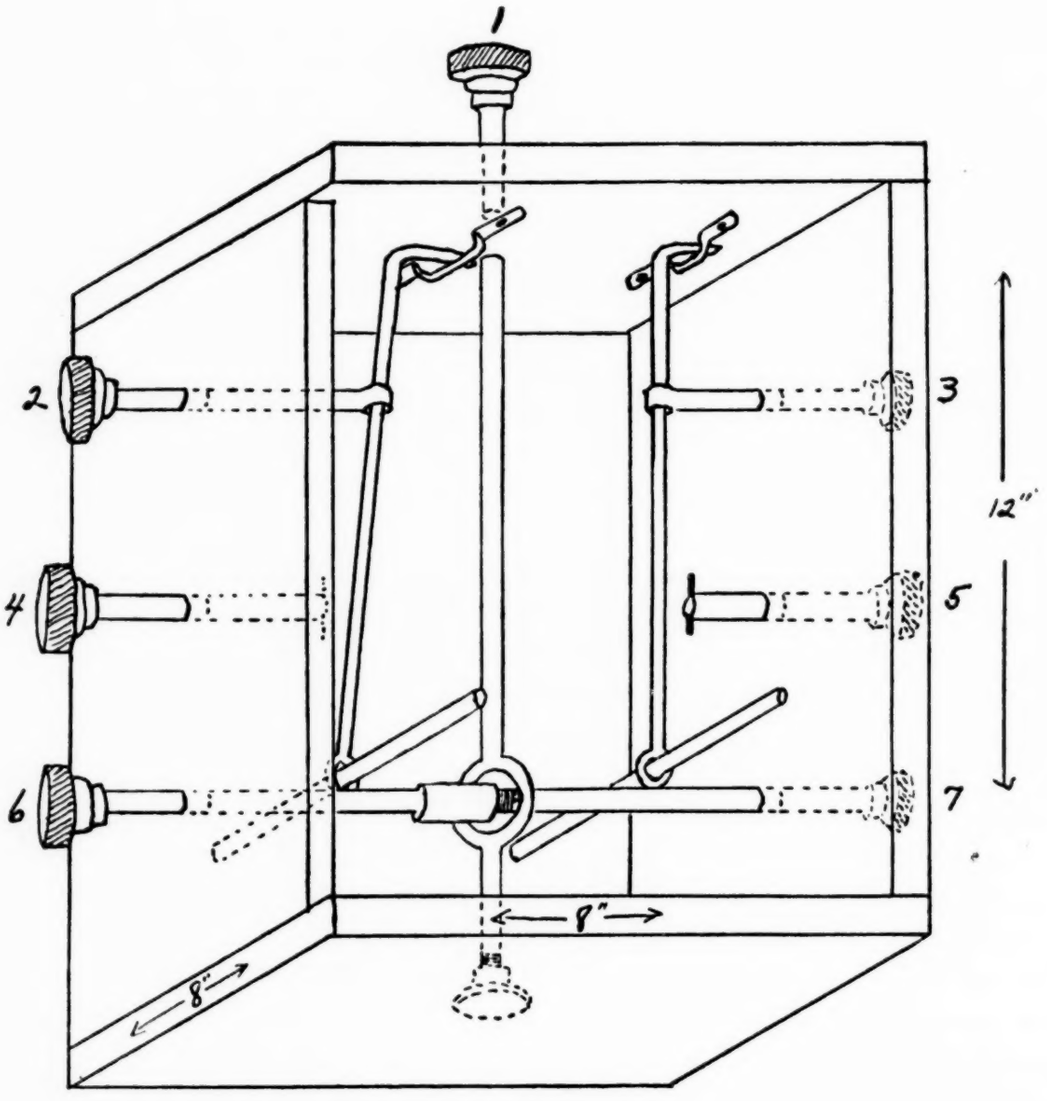

FIG. 1. The problem box.

ing conditions which, in the initial stages, maximize either the variable or the fixative aspects of the learning process. That is, learning problems which offer the possibility of greater initial variability of attack should benefit more from massed than from distributed practice. The converse of this should be equally true.

The second experiment to be described here is a check on this hypothesis at the human level. Specifically, what is the differential effect of massed and distributed practice on the learning of a problem

box versus the learning of a 10-unit multiple-U stylus maze? The assumption that the problem box presents greater potential variability in attack will be supported later by objective analysis.

The maze used in this experiment is the multiple-U stylus maze used and described by Warden (8) in 1924. The problem box was constructed and used in unpublished work by John A. McGeoch in 1928 while at the University of Arkansas. A diagram of this problem box is shown in Fig. 1. It is constructed of wood with brass knobs to be manipulated by the subjects. The problem was solved when the lid was removed. This could be done in the following manner. Separate, by unscrewing, the two knobs 6 and 7. Knobs 4 and 5 are dummies. Push in on 3 and pull out on 2. Unscrew 1 and lift up.

Results and Discussion

Procedure

Four groups of college students of both sexes were used in the following manner: Group I (N = 17) learned the maze with spaced practice, having two trials per day every other day. Group II (N = 14) learned the same maze at one sitting. The criterion of learning for both maze groups was two successive perfect runs. Group III (N = 15) used distributed practice in learning to open the puzzle box. Five minutes of practice time was given on alternate days. If the subject opened the box in less than five minutes his trial was ended and he returned again two days later. Group IV (N = 14) used massed practice which meant continuously working at the box until they succeeded in opening it within the limits of the criterion of learning. This was set at a maximum of 30 seconds and 6 moves. It was possible to open the box with five moves. A record was made of time and movements.

Learning Scores

In Table I are given the learning records of all four groups:

TABLE I

Summary of Procedure and Results

Group	N	Problem	Method of Practice	Average Trials to Learn	Average Errors to Learn	Percent Superiority		*t* Value of Difference	
						Trials	Errors	Trials	Errors
I	17	Maze	Distrib.	14.06	35.65	Distrib. 50.15% superior	Distrib. 49.07% superior	4.13	3.67
II	14	Maze	Massed	28.21	70.00				
				Ave. Moves	Ave. Time				
						Moves	Time	Moves	Time
III	15	Prob.-box	Distrib.	274.6	22′ 06″	Massed 63% superior	Massed 44% superior	6.57	7.20
IV	14	Prob.-box	Massed	101.7	12′ 43″				

These results indicate that the massed practice was significantly more beneficial with the puzzle box while the distributed practice was more beneficial in the maze situation. In both types of problems, the advantage of the better practice method was about fifty percent. The Fisher's *t* values for the differences are all beyond the one percent level of significance.

Interpretation

The differences indicated by these data present no new or startling information. Certainly it has already been established by other experimenters that maze learning profits by spaced practice and Cook (1) has shown that massed practice is superior in puzzle solving. The present data, however, provide a clearer contrast than could otherwise be obtained from the literature. Our present interest lies in the explanation which might be offered to account for these results. The hypothesis presented here revolves about the concept of variability. As already stated, "Learning problems which offer the possibility of greater initial variability of attack should benefit more from massed than from distributed practice." In presenting the present experiment as a test of this hypothesis, we must assume that the puzzle box presents greater variability of attack than the maze, at least in the beginning stages. This would seem to be a legitimate assumption since in the maze the subjects' responses are limited, at any one time, to a right-left choice. In solving the puzzle box the subject knows only that by either pushing, pulling, turning, or ignoring the seven knobs in the correct sequence, the lid can be removed. Of all the possible combinations and permutations of movements, the learner must isolate the correct sequence. Of course, as the subject approaches the solution the advantage for variability becomes less. Once the box has been correctly opened, the subjects rapidly approach the criterion; that is, the excess moves are soon eliminated. The final correct responses in both types of tasks consist of relatively stereotyped movements. Yet, the variability employed to find this pattern, clearly, is greater in the puzzle box.

This assumption can be supported by determining the ratio of the average number of movements on the first and the last trials for the two tasks. These ratios are: 78 : : 6 for the puzzle box and 14 : : 10 for the maze. The number of movements in the maze was arbitrarily set at the number of errors plus ten, the number of correct alleys.

Accepting this assumption and within the limits of these two types of learning problems, massed practice benefits those tasks offering greater initial variability of attack while distributed practice is superior for those learning problems presenting less variability. We may consider this a fact within the present experiment but certain limitations must be recognized before wide generalizations of this principle can be made.

Limitations of the Generalization

In the first place the term 'variability' is very general in its reference. In the present study we have confined its meaning to overt

motor responses used in directly attacking the maze and the puzzle box. The implicit responses are not measured or taken into account. It is not difficult to conceive of a learning situation in which one's motor responses may be stereotyped and yet reflecting a highly variable ideational attack. And of course, the converse may be equally true. But insofar as we can be sure of isolating the basic element of variability, the principle should hold true.

Another limiting factor in the range of our generalization is the stage of learning to which it is applied. The chief importance of variability is found in the early stages of the learning process where the subject is trying to find the correct solution. Having found the solution, the process of fixation becomes paramount. We should, therefore, conclude that massed practice is of relatively greater value at the beginning of learning while distributed practice aids the process of fixation toward the end. Several previous experiments have been directed at this very problem but so far the answer is not clear. One reason for this disagreement may lie in the fact that the responses being measured are not the fundamental responses actually being learned. This is similar to the first limitation of our principle described above.

Furthermore, we should recognize that the difference between the distributed and massed conditions is usually arbitrarily defined. In the two-trials-per-day condition we have the simplest case. The first trial is distributed and the second, massed. On the other hand, when one compares the results of a single continuous practice period with an arrangement of either two, five, or ten trials per day, one is really comparing true massing with a series of spaced massings. The one-and-one condition of our first experiment should provide the best opportunity to analyze the fundamental differences between distributed and massed practice.

Relation to Other Studies

Many experiments have been performed to determine the relationship between these two kinds of practice and the nature of the problem to be learned. None of these previous studies has isolated for emphasis the element of variability. A relevant study is one by Cook (1). In this experiment he adopted a similar hypothesis in that he argued that massed practice should be superior to distributed practice in the solution of a puzzle problem. His theoretical explanation for this superiority, however, differs from the one offered here. He makes a 'dualistic' interpretation, namely, that "Learning has two aspects, the intellectual and the mechanical. Intelligent learning consists in the appearance and clarification of insight, or the discovery of rela-

tionships. Mechanization is the fixing or setting of material already understood" (p. 332). Among other conclusions, he states that, "Massing should be more economical in the earlier stages and distribution in the later stages of learning. This follows from our postulate that achievement by insight is favored by immediate repetition, and the further deduction that a 'new' insight is more likely to occur in the earlier rather than later phases of the learning process" (p. 338). This, we suppose, would be Cook's way of recognizing and explaining what we should prefer to call simply variability on the ideational level. His experiment further indicates the continuity of the element of variability in problems cast at either the so-called ideational or motor level of learning.

This same point is also illustrated by an experiment by Garrett (**6**). He finds that massed practice is superior for the more complex tasks. In explanation, he says, ". . . in our easy tests the associations were simple and discrete. . . . These connections were readily acquired by our subjects and the chief function of practice was to increase the subjects' speed in the task. For this purpose spaced practice apparently has an advantage over massed. . . . In (the) more complex task each word had to be classified as to part of speech, its meaning learned, and several 'rules' applied. Time was needed for subjects to acquire tools with which to work" (p. 555). We would suggest that Garrett might also have added that the complex task required greater variability in attack and thus the advantage in massed practice.

This brief analysis of the experiments by Cook and Garrett exemplifies what could be done with other studies in which the differential effects of massed and distributed practice are analyzed. The concept of variability offers a straightforward and objective variable which is present and basic in all learning and adaptive behavior. Of course, we recognize that to explain a difference in terms of variability alone is really no final explanation at all. What we seek ultimately to know is just what the specific behavior elements are that do vary. But in the absence of this more specifically defined information, we would suggest that this concept of differential variability in attack might well be used as a descriptive element.

Summary

Previous experiments with rats have shown greater variability on the second of two daily trials than on the first. Such information led to the hypothesis that: learning problems which offer greater initial variability of attack should benefit more from massed than from distributed practice. An experimental check on the human level was interpreted as confirming this hypothesis. Certain limitations in generalizing this principle are indicated. Nevertheless, it is suggested

that this concept of variability might be used to replace or supplement other and less objectively defined concepts in attempting to account for the differential effects of massed and distributed practice.

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